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# EXTENDED ARRAY EVALUATION PROGRAM. SPECIAL REPORT NO. 8. FINAL EVALUATION OF THE DETECTION AND DISCRIMINATION CAPABILITY OF THE ALASKAN LONG PERIOD ARRAY

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Texas Instruments, Incorporated

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13. ABSTRACT


This report describes the continued evaluation of the 19-element Alaskan Long Period Array (ALPA), which was conducted by Texas Instruments Incorporated, at the Seismic Data Analysis Center over the period 1 April 1972 to 31 March 1973.

The major areas of study in the evaluation were:

- Noise analysis
- Regionalization of seismic events
- Matched filter performance
- Analysis of S-wave processing for the Kurile Islands - Kamchatka region
- Seismic event detection thresholds
- Behavior of seismic discriminants

A total of 379 events were processed and analyzed in the course of this evaluation. Where applicable, earlier ALPA data and results are discussed in conjunction with the present results.

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|---|---|---|---|---|---|---|
| | ROLE | WT | ROLE | WT | ROLE | WT |
| Seismic Noise Analysis | | | | | | |
| Regionalization | | | | | | |
| Reference Waveform Matched Filter | | | | | | |
| Chirp Matched Filter | | | | | | |
| S-Wave Detection | | | | | | |
| Seismic Event Detection Thresholds | | | | | | |
| Seismic Event Discrimination | | | | | | |

AFTAC Project No. VELA T/2705/B/ASD

# FINAL EVALUATION OF THE DETECTION AND DISCRIMINATION CAPABILITY OF THE ALASKAN LONG PERIOD ARRAY

SPECIAL REPORT NO. 8
EXTENDED ARRAY EVALUATION PROGRAM

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# SECTION I

# INTRODUCTION

This report presents the results of a continuation of the evaluation of the 19-element Alaskan Long Period Array (ALPA). It extends the analysis reported in Special Report No. 4, Extended Array Evaluation Program (Heiting, et al, 1972). Emphasis was placed on building a large data base so that detection methods and discrimination parameters of seismic events might be studied on a regional basis. Specific areas of investigation include:

- Noise analysis
- Regionalization of seismic events
- Matched filter performance
- Analysis of S-wave processing for the Kurile Islands - Kamchatka region
- Seismic event detection threshholds
- Behavior of seismic discriminants

Data from previous years has been included in the data base and, where applicable, is used in the evaluation.

The data base and the data processing methods are described in Section II. Details of the analysis of events from specific areas of interest are discussed in Sections III through VIII. Section IX summarizes results, presents conclusions and suggests possible areas of further analysis utilizing the ALPA array.

## SECTION II

## DATA BASE AND ANALYSIS METHODS

The results presented in this report are based on a compilation of seismic events and presumed explosions that were recorded in 1970, 1971, and 1972. The event parameters are listed in Appendix A. Each event is named by a three part designator consisting of a three letter abbreviation for the region, the Julian date, and the hour (GMT) of occurrence. These three parts are separated by symbols indicating the year of occurrence: slashes denote 1970 events, asterisks denote 1971 events, and dashes denote 1972 events.

### A. EVENT SELECTION

The method of selecting events to be processed from those recorded in 1972 was to compile a list of all events having epicenters in the general area of interest from the available event lists. These were: the Preliminary Determination of Epicenters Monthly Summary (PDE), the SDAC/LASA Weekly Summary (LASA), the NORSAR Seismic Event Summary (NORSAR), and, for the period 20 February to 19 March 1972, the International Seismological Month list (ISM) provided by Massachusetts Institute of Technology (Lincoln Laboratories). When more than one of these lists reported a given event, preference of choice of epicentral data was in the order ISM, PDE, LASA, NORSAR. Appendix B breaks down the disposition of the events proposed for processing.

Two major event suites were processed for 1972. The first, a winter suite, was composed of events recorded during the period 1 January 1972 through 20 March 1972. The second, a summer suite, was composed of events recorded during the period 1 June 1972 through 31 August 1972. This separation in time of the two suites was chosen to permit an investigation of possible differences in detection capability of ALPA in summer and winter. Other events outside this time period were processed, either to use as reference waveform matched filters or to build up the presumed explosion data base.

The data base for this report, including 1970 and 1971 events, totaled 524 seismic events and 32 presumed explosions. It was felt that the 1970 partial-array events could be included in this data base, since full-array and partial-array surface-wave beamforming gains have an average difference of only one dB (Heiting, et al, 1972). Therefore, there should be no appreciable difference in detection or measured surface-wave magnitudes between full-array and partial-array events.

The data base is, therefore, composed of the following time periods:

| | Number of Seismic Events | Number of Presumed Explosions |
|---|---|---|
| 1970 | 61 | 7 |
| 1971 | 96 | 13 |
| Winter, 1972 | 165 | 3 |
| Summer, 1972 | 202 | 9 |

The histogram (Figure II-1) shows the number of events from each information source and the total number processed as a function of $m_b$. Note that the PDE events predominate at higher values of $m_b$, and LASA and NORSAR events at lower values of $m_b$. The ISM events are fairly evenly distributed throughout the range of values of $m_b$.

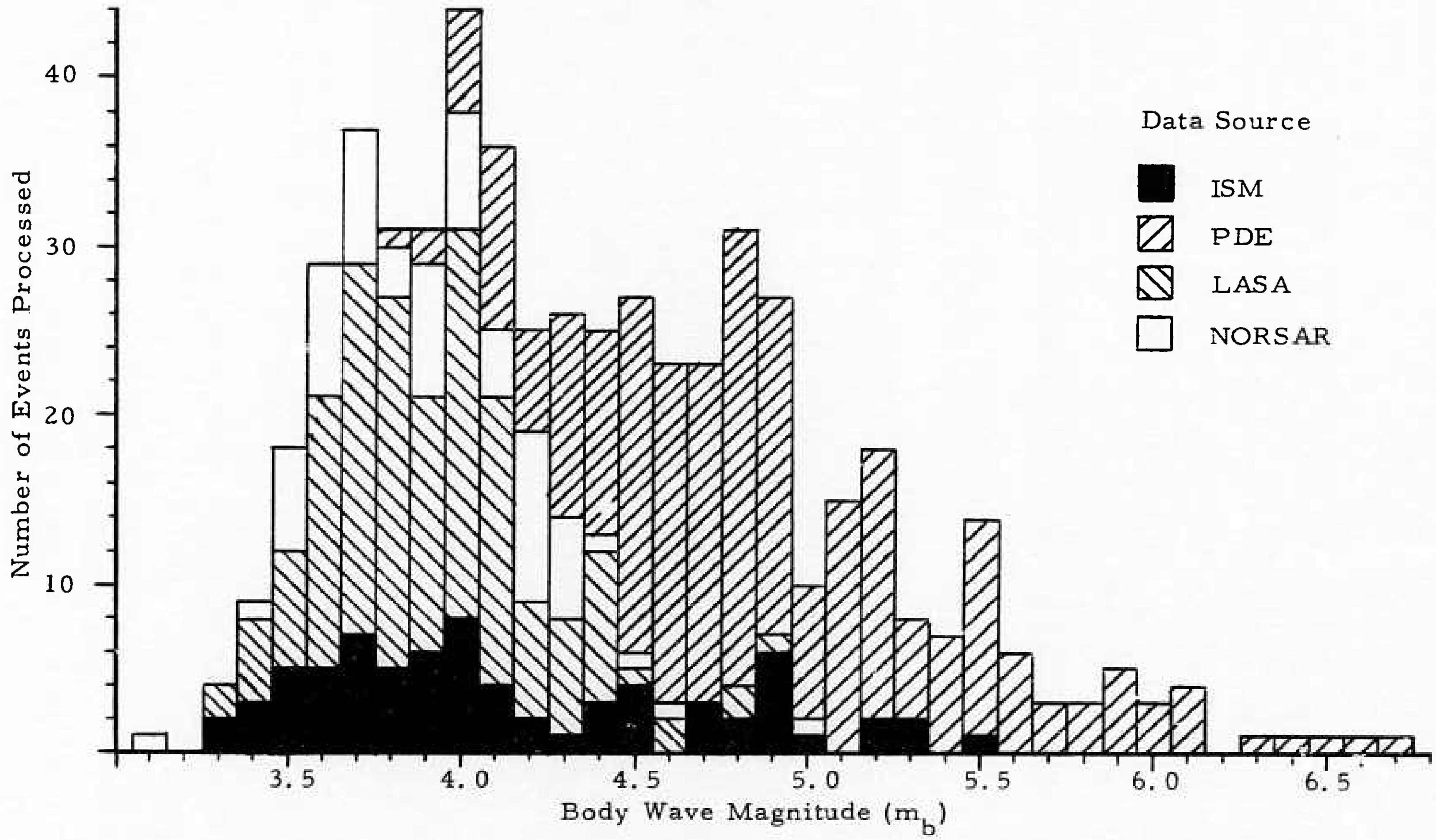



FIGURE II-1

DISTRIBUTION BY DATA SOURCE OF EVENTS PROCESSED IN 1972

B. DATA PROCESSING METHODS

1. Signal Processing

The array configuration of ALPA is shown in Figure II-2. In all processing of seismic signals discussed in this report, the raw data recorded by the triaxial seismometer at each array were rotated by means of a transformation of coordinates to form three orthogonal components of ground motion, one vertical and two horizontal. The two horizontal components are oriented such that the radial component always lies in the direction of the great circle path of the event in question and the transverse component always lies perpendicular. Therefore, the Love wave energy will always occur on the transverse (T) component and the Rayleigh wave energy on the vertical (V) and radial (R) components.

A beamsteered trace was then formed for each component of motion (T, V, and R) using all good sites. The number of good sites for each event is given in Appendix A. the velocities used in beamforming were 4.0 km/sec for the Love wave, 3.5 km/sec for the Rayleigh wave, and distance-dependent velocities for the shear waves.

The beamsteered traces were filtered using the standard 0.025-0.055 Hz bandpass filter, an appropriate reference waveform matched filter, and five chirp filters. A second bandpass filter of 0.033 to 0.083 Hz was applied to the July and August events to investigate the frequency dependence of the surface-wave magnitude measurements.

During the period 6 June 1972 through 28 August 1972, new filter amplifiers were installed at all 19 sites of ALPA, changing the quantization level from 0.565 millimicrons per computer count ($m\mu/cc$) to 0.28 $m\mu/cc$. Table II-1 lists the dates when the work was begun and completed at

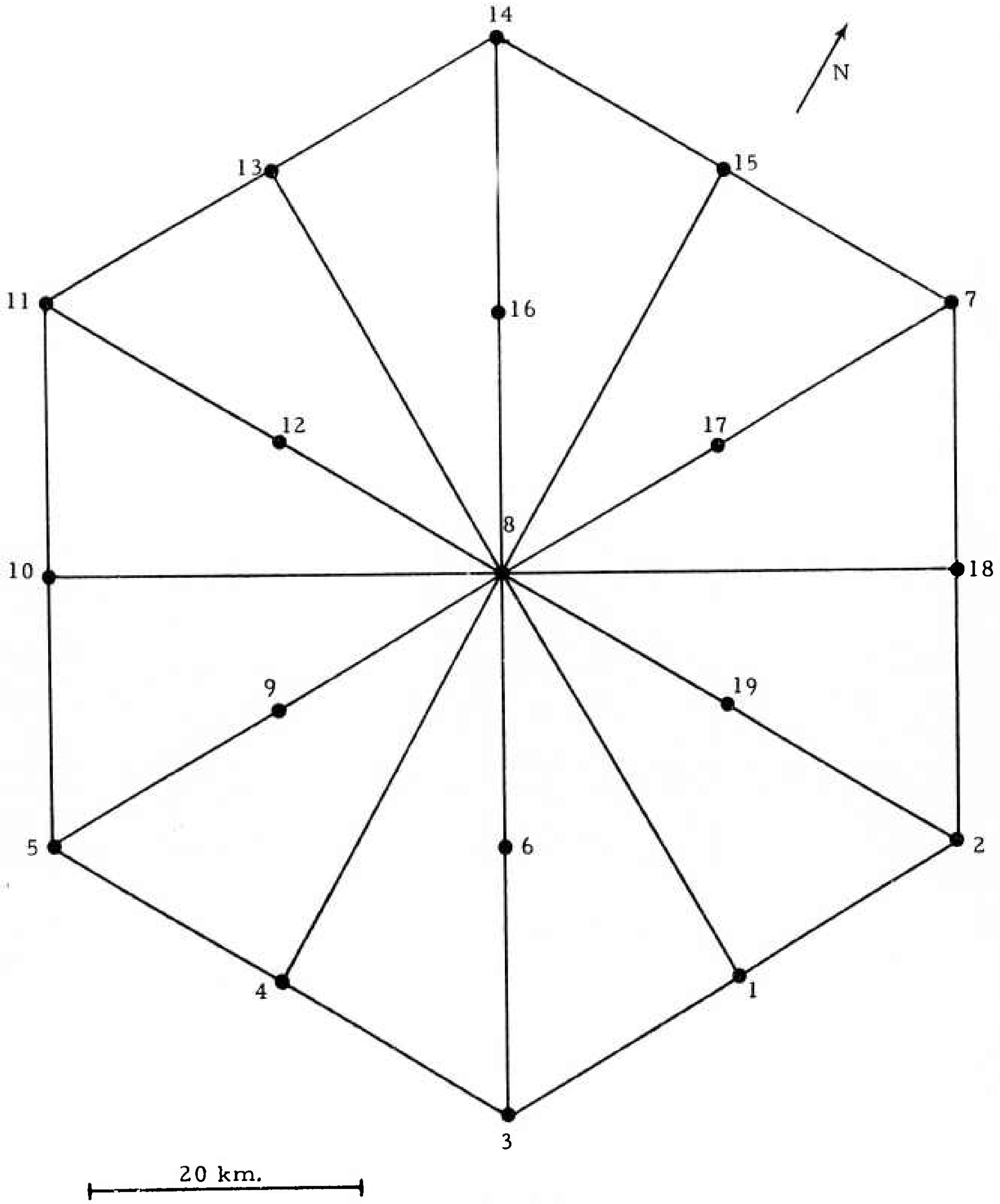



FIGURE II-2

ALPA ARRAY CONFIGURATION

TABLE II-1

AMPLIFIER CHANGE-OVER TIMES FOR ALPA

| SITE | DATE BEGUN | DATE COMPLETED |
|---|---|---|
| 1 | 29 June | 06 July |
| 2 | 20 July | 20 July |
| 3 | 06 June | 06 July |
| 4 | 22 August | 22 August |
| 5 | 24 June | 06 July |
| 6 | 13 July | 18 July |
| 7 | 19 August | 19 August |
| 8 | 19 August | 19 August |
| 9 | 19 August | 19 August |
| 10 | 28 August | 28 August |
| 11 | 23 August | 23 August |
| 12 | 23 August | 23 August |
| 13 | 23 August | 23 August |
| 14 | 17 August | 18 August |
| 15 | 17 August | 17 August |
| 16 | 17 August | 18 August |
| 17 | 20 July | 21 July |
| 18 | 20 July | 28 August |
| 19 | 12 July | 13 July |

each site. For any given day during this period, some sites were operating at the old (0.565 m$\mu$/cc) quantizing level and some at the new (0.28 m$\mu$/cc). This was corrected for in the edit process, where those sites operating at 0.28 m$\mu$/cc were scaled to the 0.565 m$\mu$/cc quantization level.

2. Noise Data Base

The raw data forming a noise sample, as recorded by the triaxial seismometers, were rotated to form three components of ground motion vertical, north-south, and east-west. The three components of the single-site noise data were plotted for three or four sites of the array to determine whether there were any seismic signals present which were not reported by any of the information sources. If a signal was found, a new time period was sought for the noise sample. These plots also allowed a check for spikes in the noise sample. Sites which had anomalously high or low power levels (as computed by the edit routine) were dropped from the analysis. The remaining good sites were then used to compute cross-power spectral matrices from which the average RMS noise levels could be measured. The resulting noise data base is listed in Appendix C. Finally, frequency-wavenumber spectra were computed to investigate the source azimuths of the peak microseismic noise.

## SECTION III
## NOISE ANALYSIS

### A. INTRODUCTION

This analysis of the ambient noise field at ALPA is an extension of the analysis performed for the preceeding year (Heiting, et al, 1972). The objectives of this analysis are to characterize the noise field in terms of the RMS noise level and the directionality of the noise and to determine whether the results are consistent with those obtained during the previous year.

One-hour noise samples were taken at approximately ten-day intervals throughout the year, as listed in Appendix C. All data were resampled to a two-second sampling interval and divided into 256-second (128-point) segments. The data were examined for sites and segments which were dead or contained spikes or glitches. These bad sites and segments were dropped from further analysis. Next, a crosspower matrix was generated for each noise sample at 52 frequencies from 0. 0 to 0. 2 Hz ($\Delta f$ = . 00391 Hz) by:

- Removing the mean from the data of each component at each site
- Discrete Fourier transforming the individual data segments
- Hanning the transforms
- Cross-multiplying to obtain the crosspower terms
- Stacking over all segments

In order to make comparisons with the results of the previous year, the spectra were not corrected for instrument response. The nominal value of 0.565 millimicrons per computer count ($m\mu$/cc) at 25 seconds (0.04 Hz) was used to normalize the power density spectra. Samples taken after 24 June 1972 were scaled appropriately to keep the normalization value at 0.565 $m\mu$/cc, as described in Section II.

## B. RMS NOISE LEVELS

Figures III-1, III-2, and III-3 illustrate the behavior of the RMS noise level for the vertical, east-west, and north-south components respectively, as observed at ALPA during the period May 1971 through December 1972. (The 1971 data was taken from Special Report No. 4, Extended Array Evaluation Program.) These RMS noise levels were computed from the average across the sites over the one-hour time gate. The bandwidth 18 to 40 seconds (0.025 to 0.055 Hz) was used in calculating the RMS noise levels.

Inspection of the data shows the RMS noise levels of the three components follow the same general pattern. There are, however, a few exceptions. For example, day 190 of 1971 shows a high RMS noise value on the north-south component with much lower values on the vertical and east-west components. The power spectra for this noise sample indicate that this is probably due to non-propagating long period noise, which is higher on the north-south component than on the other two components.

The high RMS noise values have been previously attributed to coherent noise with a spectral peak at about .055 Hz or long-period non-propagating noise with a fairly flat spectrum in the range 0.0 to 0.04 Hz. An examination of the 1971 and 1972 noise data indicate that the high RMS noise levels from day 240 to day 320 of 1971 and at days 60, 220, and 350 of 1972 are due to long-period non-propagating noise. Furthermore, the high noise

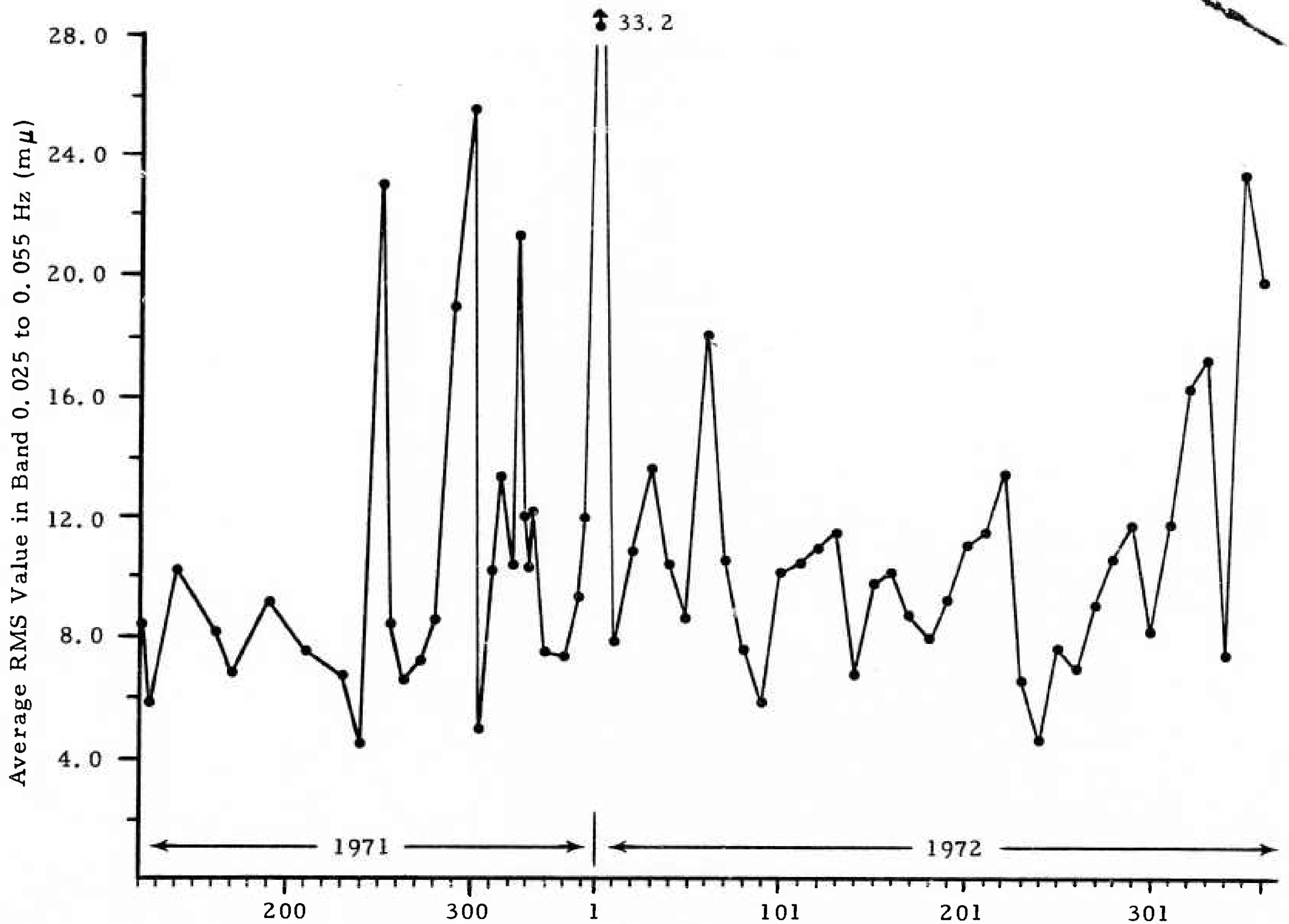



FIGURE III-1

AVERAGE RMS NOISE LEVEL IN 0.025 TO 0.055 Hz BAND (VERTICAL COMPONENT)

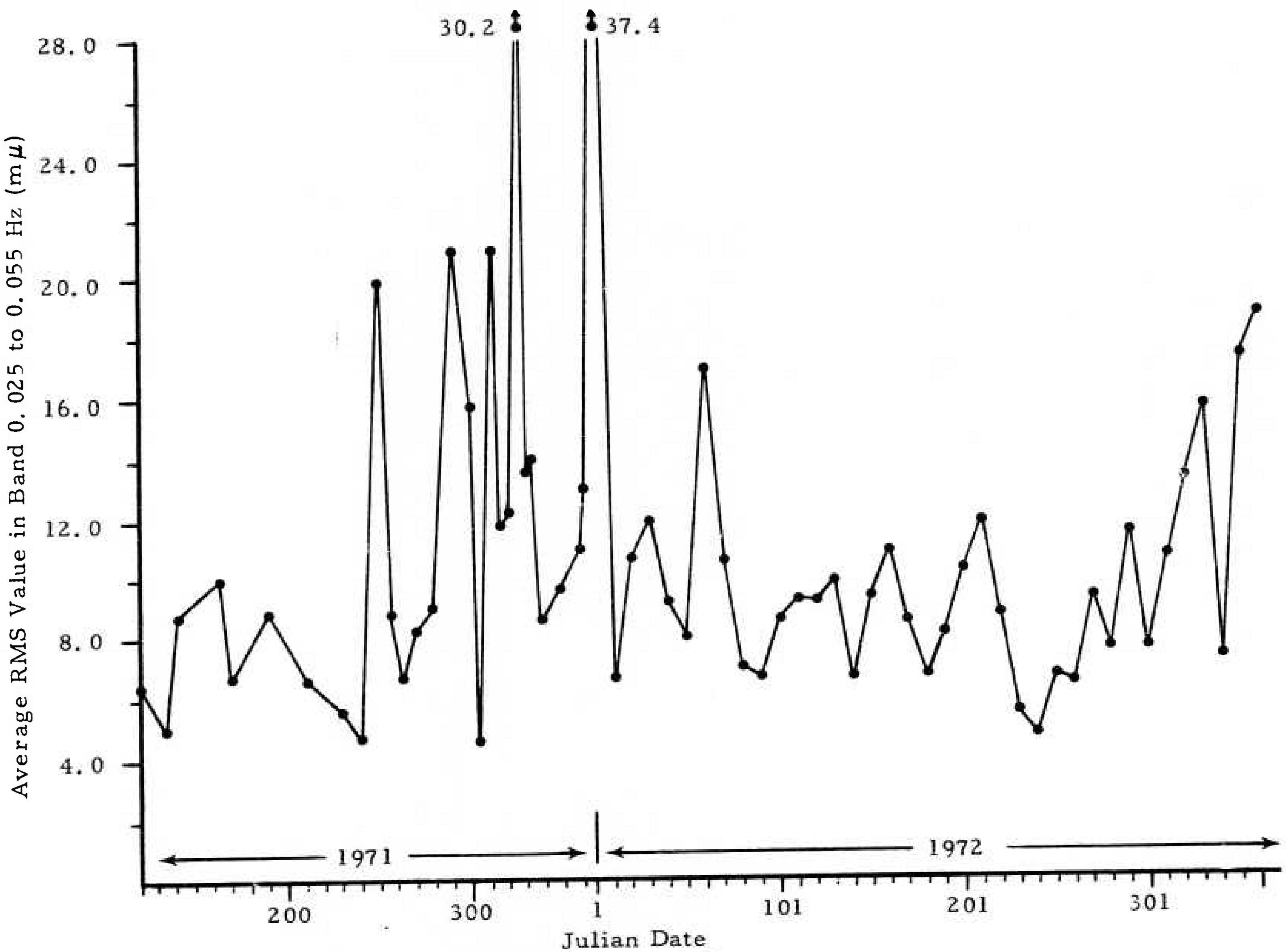



FIGURE III-2

AVERAGE RMS NOISE LEVEL IN 0.025 TO 0.055 Hz BAND (EAST-WEST COMPONENT)

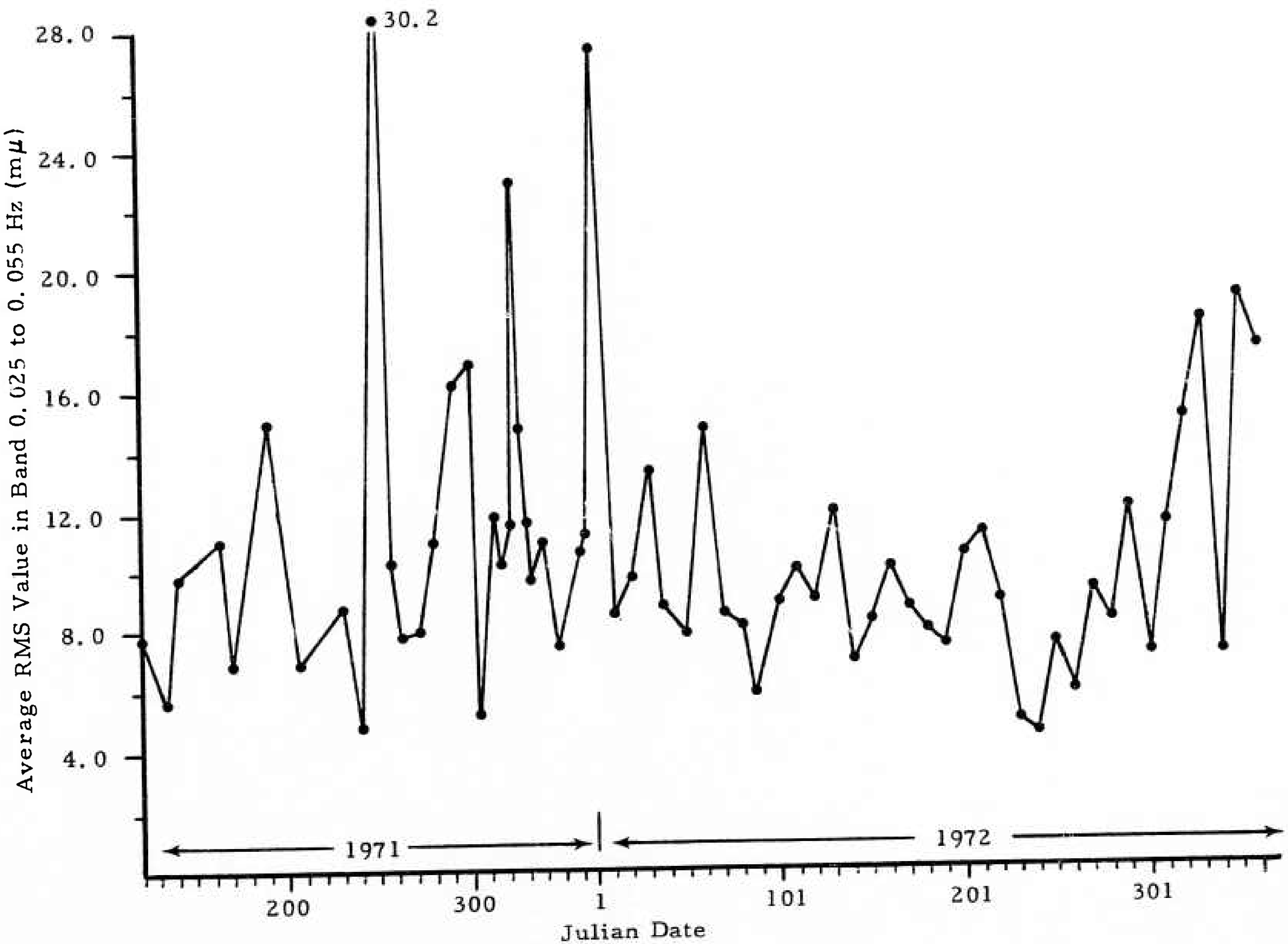



FIGURE III-3

AVERAGE RMS NOISE LEVEL IN 0.025 TO 0.055 Hz BAND (NORTH-SOUTH COMPONENT) levels at days 330 and 361 of 1972 are at least partly due to long-period non-propagating noise. However, the high noise levels at day 322 of 1971 and days 1 and 320 of 1972, as evidenced by the power spectra, do not contain long-period non-propagating noise and are due to coherent microseismic noise. This coherent noise may be storm-generated.

An interesting feature of the noise data is found in the RMS noise level data for the period day 241 of 1972 through day 361 of 1972. These data indicate an upward trend. This trend is in contrast to the corresponding period in 1971, where the data imply a fairly constant background RMS noise level punctuated by short-duration bursts of higher-energy noise. To determine whether this is a real difference in the behavior of the noise field would require more noise samples from the day 241 to day 361 period and an extension of this period to approximately day 100 of 1973.

The following conclusions may be drawn from the RMS noise level data:

- With the exception of the unexplained upward trend in the data at the end of 1972, the RMS noise values appear to have a fairly constant background level throughout the year, ranging between 7 and 10 millimicrons.
- The higher RMS noise levels for the most part appear to be due to bursts of long-period non-propagating noise superimposed on the background noise level. A few of the high RMS noise levels may be due to storm generated noise.

## C. DIRECTIONALITY OF THE NOISE

The source azimuths of microseismic noise were measured on high-resolution frequency-wavenumber spectra. Each of the frequency-wavenumber spectra was computed at the frequency corresponding to the maximum value of the power density spectrum for that sample. This peak frequency, which ranged from 0.047 to 0.063 Hz, was used because it is generally highly coherent. Azimuths were computed only from vertical-component data, since the horizontal components contain both Love and Rayleigh energy. The peak frequencies, azimuths, and velocities are listed in Appendix C.

The source azimuths of microseismic noise as recorded at ALPA are shown in Figure III-4. In this figure, the source azimuth of the peak microseismic noise is indicated by an arrowhead. The source azimuths of the clearly discernable secondary peaks (2 dB or less below the primary peak) are indicated by circles. The range of source azimuths for the continuum of energy 6 dB or less below the primary peak is indicated by a line.

The results of this analysis agree with the results of the analysis of the previous year (Heiting, et al, 1972). The predominant microseismic noise source azimuth during 1972 lies in the range of azimuths 125$^o$ to 150$^o$, which coincides with the western Canada and United States coastlines. A secondary range of source azimuths was found between 180$^o$ and 230$^o$, which coincides with the Cook Inlet region of Southern Alaska. A possible explanation for these apparent microseismic noise sources is that storm-generated waves are channeled into the Alexander Archipelago along the western coast and the Cook Inlet, resulting in the release of relatively large amounts of wave energy along restricted coastal areas.

In summary, the results of the analysis of the ambient noise field at ALPA agree with those of the preceeding year. High levels of long-period noise occur only in the winter months. The source azimuths of microseismic noise as recorded at ALPA rarely coincide with azimuths to the area of interest.

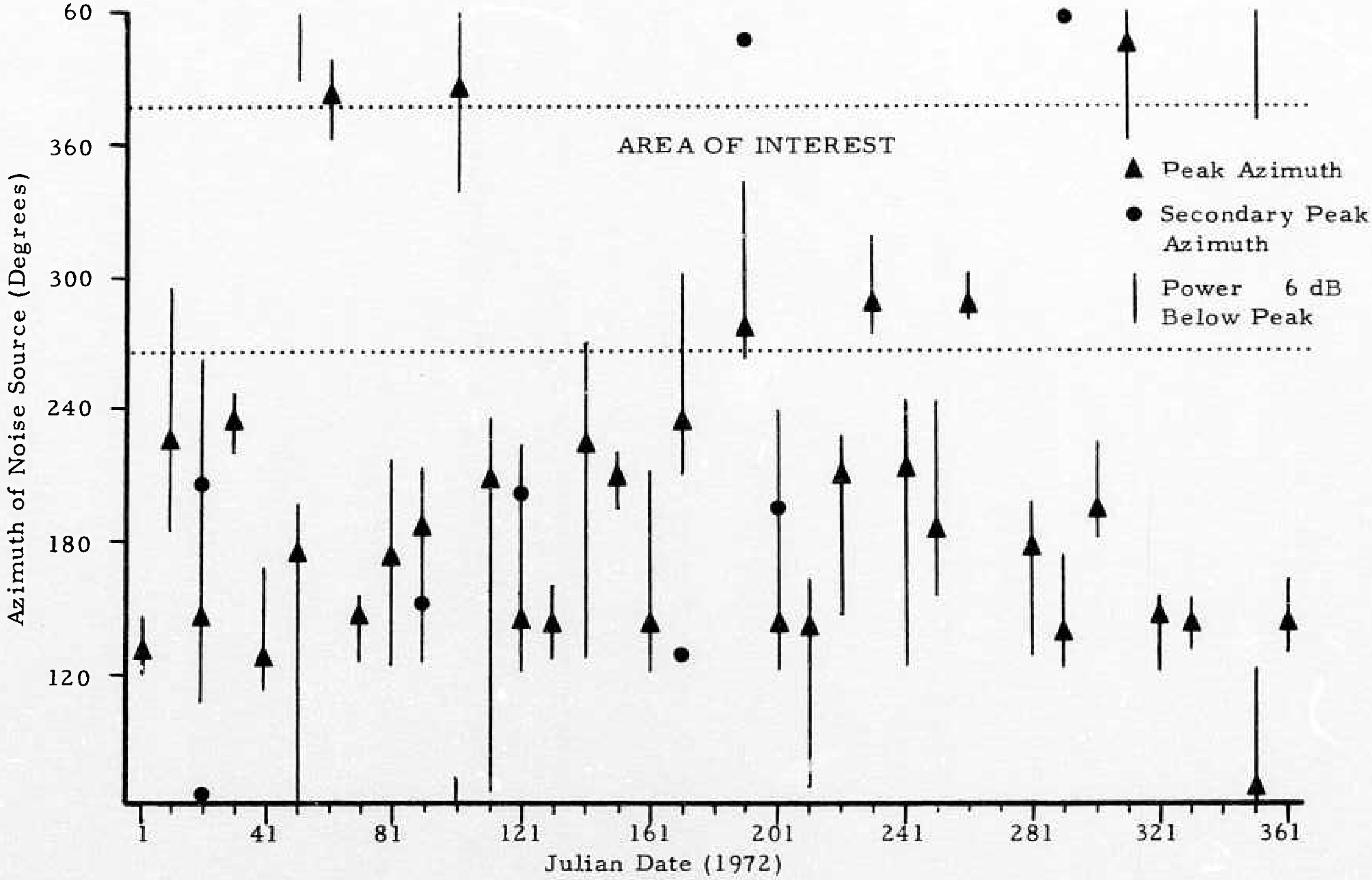



FIGURE III-4

VERTICAL COMPONENT NOISE SOURCE AZIMUTHS

## SECTION IV
## REGIONALIZATION OF SEISMIC EVENTS

The data base was regionalized by mapping the epicenters of all available events. Each set of closely grouped events was then considered to form the population of a seismic region. This decomposition of the data base into separate regional populations made possible an investigation of matched filter responses, detection thresholds, and standard discriminants in more detail than was previously possible.

The regions so chosen are:

- Southern Kurile Islands (KUR) This region contains events with epicenters in or near the Kurile trench having epicentral distances ($\Delta$) to ALPA of approximately $35^{\circ}$-$40^{\circ}$.
- Kamchatka (KAM) This region contains events with epicenters along the eastern coast of Kamchatka, near the Komandorsky Islands, and in the northern end of the Kurile trench. These events have epicentral distances of about $25^{\circ}$-$30^{\circ}$.
- Central Asia (CA) This region contains events with epicenters in Sinkiang, Tibet, and the Hindu Kush. These events have epicentral distances of about $60^{\circ}$-$80^{\circ}$.
- Caspian Sea (CSP) This region contains events with epicenters near the Caspian Sea. It includes events from the Caucasus Mountains and northwestern Iran. These events have epicentral distances of about $70^{\circ}$-$80^{\circ}$.

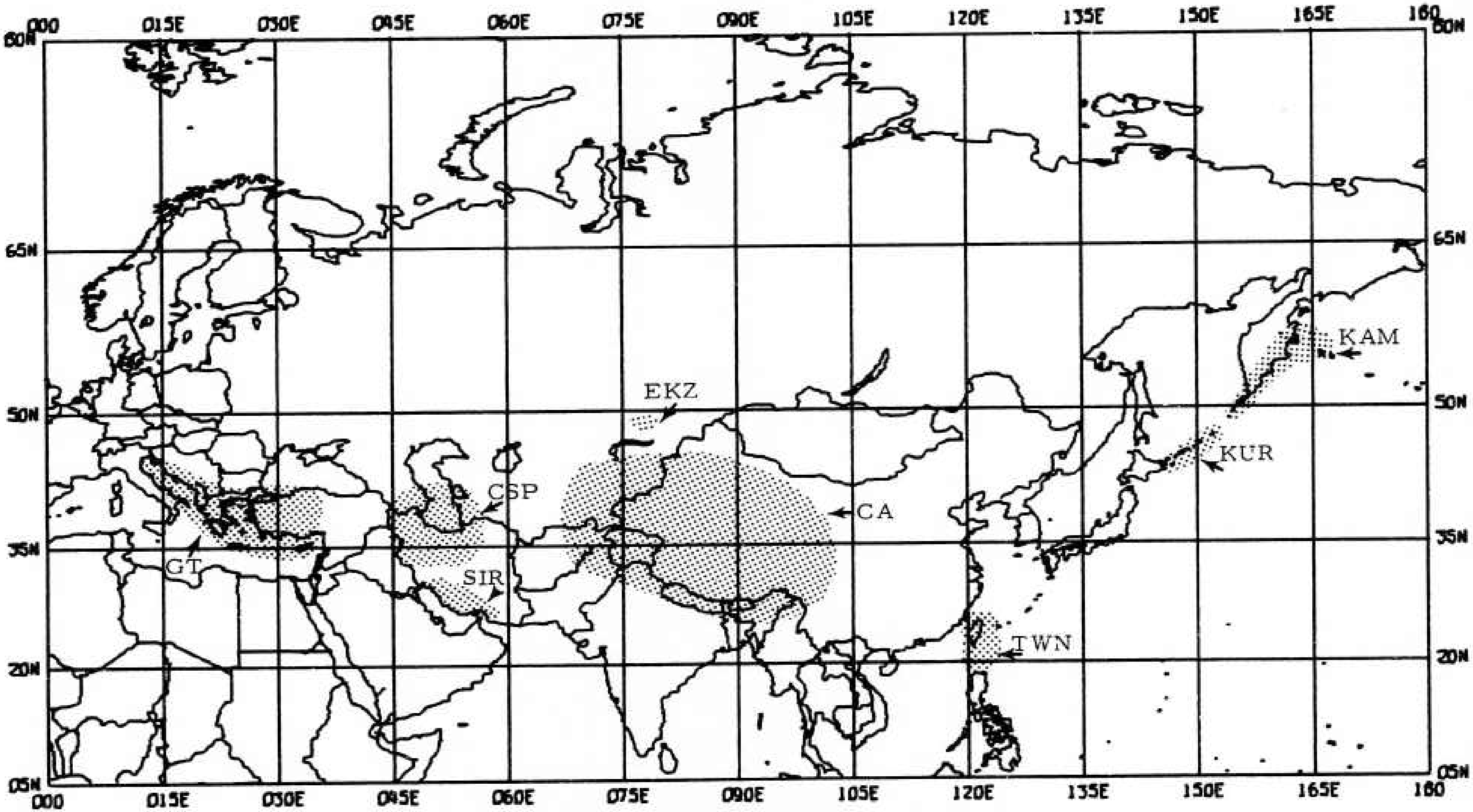
- Southern Iran (SIR) This region contains events with epicenters near the coast of southeastern Iran. These events have epicentral distances of about 85°.

- Greece-Western Turkey (GT) This region contains events with epicenters in Greece, Italy, the Adriatic Sea, the Aegean Sea, and Western Turkey. These events have epicentral distances of about 70°-80°.

- Eastern Kazakh Test Area (EKZ) This region contains events which have epicenters in the Eastern Kazakh test area and which are all presumed explosions. These events have epicentral distances of approximately 60°.

- Taiwan (TWN) This region contains events which have epicenters in or near Taiwan and the southern Ryukyu Islands. These events have epicentral distances of approximately 70°.

The locations of these regions are shown in Figure IV-1. The events included in each of these regions are so noted in Appendix A.




MILLER MODIFIED MERCATOR PROJECTION
MAP SCALE: 0.750 IN./ 15 DEG. LONGITUDE

FIGURE IV-1

LOCATION OF THE SEISMIC REGIONS

# SECTION V
# MATCHED FILTER PERFORMANCE

## A. INTRODUCTION

Matched filters were applied to long-period signals as recorded at ALPA to evaluate their effectiveness in increasing the signal-to-noise ratio of dispersed seismic signals. Both the reference waveform matched filters and chirp filters were applied to the transverse Love wave and the vertical and radial Rayleigh waves of a test event. The goals of this analysis were:

- To determine potential signal-to-noise ratio gains of reference waveform and chirp filters
- To compare the relative effectiveness of reference waveform and chirp filters
- To evaluate the effectiveness of matched filters in increasing the surface-wave detection capability of ALPA.

Matched filter performance was analyzed in terms of signal-to-noise ratio improvement over the equivalent bandpass signal-to-noise ratio. Each signal-to-noise ratio was calculated as the ratio of the peak value of the signal waveform to the RMS value of the noise measured in a gate ahead of the signal. The signal-to-noise ratio improvement of a matched filtered beam over the corresponding bandpass beam, expressed in decibels, is:

$$\text{Improvement (dB)} = 20 \log (SNR_{matched}/SNR_{BP})$$

Since the signals are not noise-free, the signal amplitudes are actually signal plus noise amplitudes. For this reason, we will refer to the signal plus noise-to-noise ratio (SNNR) from this point on.

## B. REFERENCE WAVEFORM MATCHED FILTER RESULTS

A suite of 27 reference waveform events was selected for this evaluation of reference waveform matched filtering. The approximate locations of these events are shown in Figure V-1. The name and associated parameters for the event corresponding to each numbered location in the figure are given in Table V-1. The selection criteria were: good SNNR, shallow focus (less than 60 km), and location in an area where no reference waveform event has been previously selected. The length of the reference waveforms was chosen in the following manner: for events at large epicentral distances, the length was selected to include possible multipath energy, since small changes in event epicenter location would not be expected to significantly change the multipath structure. This situation is reversed for events at small epicentral distances; for such events, small changes in event epicenter location could significantly change the multipath structure. Therefore, the lengths of reference waveforms having small epicentral distances were chosen so as to exclude any possible multipath energy.

The SNNR improvements obtained from reference waveform matched filtering of 77 events from 1972 are given in Table V-2, along with the reference waveform-test event separation. (There is no duplication of test events for different reference waveform filters.) The letters in paranthesis to the left of the name of each reference waveform refer to the region (Section IV) to which it belongs.

Considering those reference waveforms for which there are enough test events to make discussion meaningful, the following statements can be made about the behavior of individual reference waveform filters.

- Reference waveform KAM/242/00 yielded good Love wave improvement and poor Rayleigh wave improvement. The mean Rayleigh wave improvements are not as good as those obtained last year using a different set of test events.

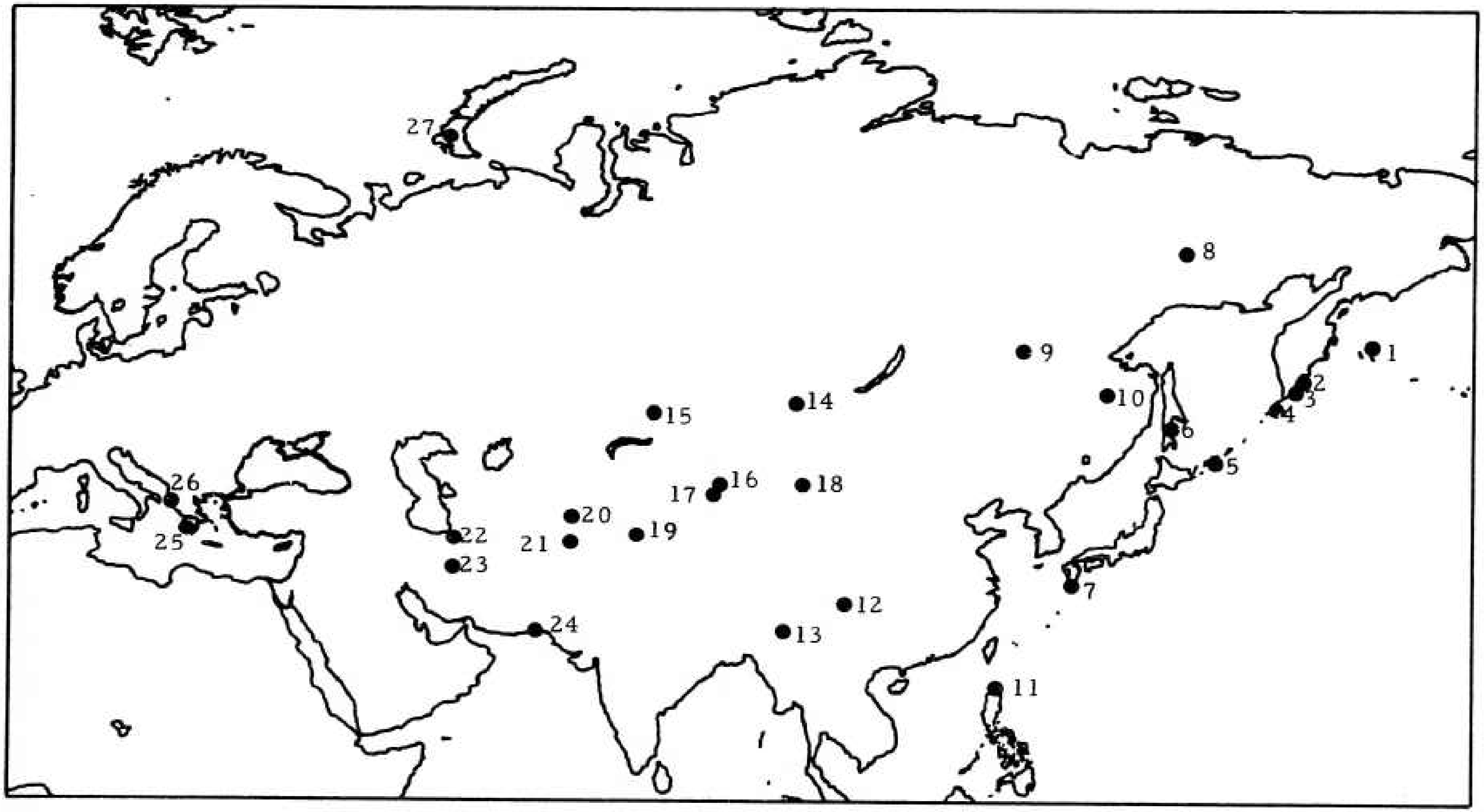



FIGURE V-1

REFERENCE WAVEFORM EVENT LOCATIONS

TABLE V-1

REFERENCE WAVEFORM EVENT DATA

| Event Name | Date M/ D/ Y | Time (hr-min-sec) | Lat. ($^oN$) | Lon. ($^oE$) | Depth (km) | $m_b$ | Location number Fig. V-1 |
|---|---|---|---|---|---|---|---|
| KOM-171-01 | 06/19/72 | 01-43-48 | 54.4 | 168.6 | 33 | 5.0 | 1 |
| KAM*206*03 | 07/31/71 | 03-45-05 | 52.6 | 160.7 | 33 | 4.5 | 2 |
| KAM/242/00 | 08/30/70 | 00-38-40 | 52.1 | [illegible] | 33 | 5.2 | 3 |
| KUR-063-23 | 02/03/72 | 23-10-40 | 50.2 | 155.7 | 33 | 4.5 | 4 |
| KUR/219/01 | 08/07/70 | 01-43-19 | 43.8 | 148.3 | 33 | 5.0 | 5 |
| SAK*251*16 | 09/06/71 | 16-59-53 | 48.0 | 143.0 | 16 | 5.9 | 6 |
| KYU/206/22 | 07/25/70 | 22-41-11 | 32.2 | 131.7 | 34 | 6.1 | 7 |
| SIB/156/10 | 06/05/70 | 10-31-54 | 63.4 | 146.2 | 33 | 5.5 | 8 |
| ERS-165-10 | 06/13/72 | 10-45-05 | 54.9 | 126.4 | 33 | 4.8 | 9 |
| ERS/241/14 | 08/29/70 | 14-59-23 | 51.1 | 135.3 | 33 | 5.4 | 10 |
| PIP-039-03 | 02/08/72 | 03-37-52 | 19.3 | 122.0 | 50 | 5.7 | 11 |
| CHI/212/13 | 07/31/70 | 13-10-47 | 28.6 | 103.6 | 25 | 5.5 | 12 |
| BUR/210/10 | 07/29/70 | 10-16-19 | 26.0 | 95.4 | 59 | 6.5 | 13 |
| USM-057-23 | 02/26/72 | 23-31-09 | 50.6 | 97.3 | 33 | 5.3 | 14 |
| KAZ/249/04 | 09/06/70 | 04-02-57 | 49.8 | 78.1 | 0 | 5.6 | 15 |
| SIN-002-10 | 01/02/72 | 10-27-35 | 42.8 | 87.3 | 19 | 5.2 | 16 |
| SIN-047-23 | 02/16/72 | 23-19-20 | 41.7 | 80.7 | 29 | 4.8 | 17 |
| SIN-084-08 | 03/24/72 | 08-11-53 | 42.9 | 87.4 | 33 | 5.0 | 18 |
| SIN*219*15 | 08/05/71 | 15-21-53 | 36.1 | 77.7 | 33 | 4.8 | 19 |
| TAD-077-09 | 03/17/72 | 09-17-10 | 40.1 | 69.7 | 26 | 5.2 | 20 |
| HIN-176-15 | 06/24/72 | 15-29-22 | 36.2 | 69.7 | 47 | 6.0 | 21 |
| IRA/242/16 | 08/30/70 | 16-17-31 | 37.4 | 56.0 | 33 | 5.1 | 22 |
| IRA-101-02 | 04/10/72 | 02-07-28 | 33.2 | 56.6 | 33 | 6.3 | 23 |
| PAK-028-10 | 01/28/72 | 10-26-54 | 26.6 | 66.3 | 33 | 5.9 | 24 |
| GRC/184/00 | 07/03/70 | 00-41-01 | 38.7 | 20.4 | 33 | 5.1 | 25 |
| ALB/231/02 | 08/19/70 | 02-01-53 | 41.4 | 19.8 | 33 | 5.2 | 26 |
| CRS/287/05 | 10/14/70 | 05-59-57 | 73.3 | 55.1 | 0 | 6.7 | 27 |

TABLE V-2

REFERENCE WAVEFORM MATCHED FILTER IMPROVEMENTS
(PAGE 1 OF 5)

| Event Designation | RMF/Test Separation (km) | dB SNNR Improvement Over Equivalent Bandpass Filter (.025 - .055 Hz) | | |
|---|---|---|---|---|
| | | T | V | R |
| (KAM) KUR-063-23 | ← (RMF) | | | |
| KUR-235-14AL | 55 | 9.1 | 7.7 | 4.7 |
| KUR-194-00QC | 89 | 5.0 | 4.2 | 4.3 |
| KUR-218-22AL | 132 | 3.4 | 4.5 | 1.6 |
| KUR-209-00AL | 221 | 3.2 | 10.3 | 8.3 |
| KUR-154-01AL | 286 | 1.9 | 4.0 | 4.3 |
| KUR-216-02QC | 426 | -0.5 | 2.3 | 2.4 |
| Mean Improvement for KUR-063-23 | | 3.7 | 5.5 | 4.3 |
| Standard Deviation | | 3.2 | 2.9 | 2.3 |
| (KAM) KOM-171-01 | ← (RMF) | | | |
| KOM-183-02AL | 175 | 0.3 | 3.0 | 3.1 |
| KOM-229-10QC | 210 | 2.1 | 1.5 | 4.5 |
| KOM-180-04AL | 289 | 2.8 | 3.6 | 3.6 |
| KOM-153-21TD | 303 | 5.9 | 3.6 | 1.5 |
| KAM-186-13AL | 366 | 3.8 | 1.3 | 3.3 |
| KAM-229-21AL | 397 | 3.6 | 1.4 | 2.9 |
| Mean Improvement for KOM-171-01 | | 3.1 | 2.4 | 3.1 |
| Standard Deviation | | 1.9 | 1.1 | 1.0 |
| (KAM) KAM*206*03 | ← (RMF) | | | |
| KAM-173-00QC | 49 | -1.3 | -5.3 | -1.7 |
| KAM-180-14AL | 49 | 4.0 | 0.6 | 1.0 |
| KAM-192-12AL | 130 | 2.6 | 1.9 | 1.0 |
| KAM-173-10QC | 157 | 1.7 | -3.7 | -0.7 |
| KAM-177-17AL | 162 | -1.0 | 1.6 | 0.5 |
| KAM-179-06AL | 192 | 3.1 | -2.6 | -2.1 |
| KAM-193-08QC | 306 | -1.3 | -2.7 | -2.8 |
| KAM-168-09AL | 378 | 1.8 | 1.7 | -1.0 |
| KAM-158-10AL | 418 | -1.4 | 1.9 | -1.8 |
| KAM-157-04AL | 429 | 1.8 | 1.0 | 2.6 |
| Mean Improvement for KAM*206*03 | | 1.0 | -0.6 | -0.5 |
| Standard Deviation | | 2.0 | 2.7 | 1.6 |

TABLE V-2

REFERENCE WAVEFORM MATCHED FILTER IMPROVEMENTS
(PAGE 2 OF 5)

| Event Designation | RMF/Test Separation (km) | dB SNNR Improvement Over Equivalent Bandpass Filter (.025 - .055 Hz) | | |
|---|---|---|---|---|
| | | T | V | R |
| (KAM) KAM/242/00 | ← (RMF) | | | |
| KAM-231-19AL | 102 | 5.5 | 0.2 | 0.0 |
| KAM-156-07AL | 147 | 4.0 | -1.7 | 0.1 |
| KAM-233-08QC | 164 | 4.2 | -3.5 | -2.0 |
| KAM-199-08AL | 322 | 6.0 | 0.6 | 3.1 |
| Mean Improvement for KAM/242/00 | | 4.9 | -1.1 | 0.3 |
| Standard Deviation | | 1.0 | 1.9 | 2.1 |
| (SIR-CSP) IRA-101-02 | ← (RMF) | | | |
| IRA-187-16AL | 497 | -0.7 | 6.8 | 6.1 |
| IRA-216-22AL | 557 | -0.2 | -2.3 | -1.1 |
| IRA-155-08AL | 579 | -0.2 | 0.8 | -0.1 |
| IRA-196-13QC | 648 | 5.6 | 6.2 | 7.8 |
| IRA-184-12AL | 648 | 2.0 | 5.5 | 3.7 |
| IRA-182-17QC | 667 | 0.6 | -0.7 | 1.3 |
| IIQ-175-08AL | 969 | -1.8 | -0.4 | 1.6 |
| IIQ-166-04AL | 977 | 4.0 | -4.3 | -4.3 |
| Mean Improvement for IRA-101-02 | | 1.2 | 1.4 | 1.9 |
| Standard Deviation | | 2.4 | 4.3 | 3.9 |
| (TWN) PIP-039-03 | ← (RMF) | | | |
| TWN-212-16AL | 223 | 2.5 | 7.2 | 7.0 |
| TWN-178-08QC | 267 | -0.2 | 10.1 | 9.8 |
| TWN-160-09AL | 274 | -1.0 | 10.9 | 13.6 |
| TWN-198-13AL | 494 | -0.6 | 6.6 | 4.1 |
| TWN-182-18TD | 563 | 0.6 | 3.4 | 4.7 |
| RYU-155-02AL | 591 | 0.0 | 3.8 | 3.3 |
| RYU-197-02AL | 631 | 0.5 | 8.8 | 10.5 |
| Mean Improvement for PIP-039-03 | | 0.3 | 5.8 | 7.6 |
| Standard Deviation | | 1.1 | 3.2 | 3.8 |

TABLE V-2

REFERENCE WAVEFORM MATCHED FILTER IMPROVEMENTS
(PAGE 3 OF 5)

| Event Designation | RMF/Test Separation (km) | dB SNNR Improvement Over Equivalent Bandpass Filter (.025 - .055 Hz) | | |
|---|---|---|---|---|
| | | T | V | R |
| (EKZ) KAZ/249/04 | ←(RMF) | | | |
| EKZ-345-04AL | 0 | 0.3 | 5.8 | 4.2 |
| EKZ-159-01QD | 7 | 4.5 | 6.4 | 5.9 |
| EKZ-307-01AL | 78 | -0.9 | 5.5 | 4.6 |
| Mean Improvement for KAZ/249/04 | | 1.3 | 5.9 | 4.9 |
| Standard Deviation | | 2.8 | 0.5 | 0.9 |
| PAK-028-10 | ←(RMF) | | | |
| PAK-162-11AL | 179 | 3.8 | 6.0 | 7.2 |
| PAK-179-06QC | 522 | -0.3 | 4.0 | 3.1 |
| PAK-179-10AL | 522 | -1.3 | 2.6 | 0.6 |
| IRA-221-19AL | 550 | -1.3 | 4.0 | 4.7 |
| Mean Improvement for PAK-028-10 | | 0.2 | 4.1 | 3.9 |
| Standard Deviation | | 2.4 | 1.4 | 2.8 |
| CHI/212/13 | ←(RMF) | | | |
| TSI-156-23AL | 797 | 3.5 | 1.0 | 2.3 |
| TIB-198-02AL | 854 | 2.7 | -2.8 | 0.9 |
| TSI-243-15AL | 1117 | 6.0 | 1.0 | 3.6 |
| (CA) BUR/210/10 | ←(RMF) | | | |
| BUR-179-09AL | 122 | -1.9 | 1.3 | 2.1 |
| TSI-180-03AL | 886 | 0.4 | 0.8 | 0.1 |
| (CA) SIN-047-23 | ←(RMF) | | | |
| SIN-154-06AL | 42 | 5.2 | 3.3 | 5.5 |
| SIN-187-01AL | 324 | 3.1 | 3.9 | 4.9 |
| (CA) SIN*219*15 | ←(RMF) | | | |
| KTB-206-14AL | 263 | 0.8 | 0.6 | -2.4 |
| TIB-170-04AL | 595 | -4.4 | -5.0 | -1.8 |

TABLE V-2

REFERENCE WAVEFORM MATCHED FILTER IMPROVEMENTS
(PAGE 4 OF 5)

| Event Designation | RMF/Test Separation (km) | dB SNNR Improvement Over Equivalent Bandpass Filter (.025 - .055 Hz) | | |
|---|---|---|---|---|
| | | T | V | R |
| (CA) SIN-084-08 | ← (RMF) | | | |
| SIN-187-04AL | 88 | 1.4 | 5.4 | 1.9 |
| SIN-192-19AL | 112 | -0.7 | 1.6 | 1.1 |
| (CA) HIN-176-15 | ← (RMF) | | | |
| HIN-178-20AL | 67 | 3.6 | 0.7 | -1.2 |
| AFG-211-17AL | 492 | 1.8 | 4.5 | 3.3 |
| (CA) SIN-002-10 | ← (RMF) | | | |
| TSI-154-16AL | 856 | -1.6 | -3.1 | 0.4 |
| (CA) TAD-077-09 | ← (RMF) | | | |
| AUB-181-03QC | 198 | 2.0 | -2.4 | 1.5 |
| (CSP) IRA/242/16 | ← (RMF) | | | |
| IRA-202-13AL | 179 | 5.1 | 6.7 | 6.4 |
| IIQ-164-13AL | 1000 | -2.4 | 0.5 | 4.3 |
| IIQ-165-00AL | 1000 | 0.6 | -1.1 | 3.4 |
| (GT) GRC/184/00 | ← (RMF) | | | |
| MED-187-18AL | 222 | 0.8 | 0.7 | 1.5 |
| TUR-216-21AL | 1079 | 2.7 | 5.6 | 5.4 |
| (GT) ALB/231/02 | ← (RMF) | | | |
| YUG-243-00AL | 412 | 2.4 | 3.0 | 0.8 |
| (KUR) KUR/219/01 | ← (RMF) | | | |
| KUR-232-00AL | 34 | 2.0 | 4.8 | 3.4 |
| CRS/287/06 | ← (RMF) | | | |
| NVZ-241-05AL | 0 | 2.5 | 10.6 | 6.5 |

TABLE V-2

REFERENCE WAVEFORM MATCHED FILTER IMPROVEMENTS
(PAGE 5 OF 5)

| Event Designation | RMF/Test Separation (km) | dB SNNR Improvement Over Equivalent Bandpass Filter (.025 - .055 Hz) | | |
|---|---|---|---|---|
| | | T | V | R |
| SAK*251*16 | ← (RMF) | | | |
| KUR-211-21AL | 978 | 1.6 | 0.5 | 0.6 |
| ERS/241/14 | ← (RMF) | | | |
| ERS-165-10QD | 729 | 1.9 | 4.2 | 0.9 |
| SIB/156/10 | ← (RMF) | | | |
| SIB-238-04AL | 912 | 0.4 | 3.2 | 3.9 |
| ERS-165-10 | ← (RMF) | | | |
| ERS-222-20AL | 217 | 2.5 | 1.0 | 1.0 |
| USM-057-23 | ← (RMF) | | | |
| CRS-244-14AL | 230 | 5.6 | 2.9 | 3.0 |
| KYU/206/22 | ← (RMF) | | | |
| RYU-209-16AL | 764 | 1.1 | 6.0 | 5.8 |

- Reference waveform KUR-063-23 yielded good Rayleigh wave improvements for all test events and good Love wave improvements on all but the last two test events. This decrease in Love wave improvement appears to be due to increases in reference waveform-test event separation.

- Reference waveform KOM-171-01 yielded fairly good Rayleigh and Love wave improvements. The average improvements for the three components are essentially the same.

- Reference waveform KAM*206*03 yielded poor Rayleigh and Love wave improvements. This indicates that this reference waveform is not representative of the events occurring near its epicentral location. Therefore, this reference waveform should be replaced.

- Reference waveform IRA-101-02 yielded poor Rayleigh and Love wave improvements on five test events and good Rayleigh wave improvements on three test events (located near each other). Therefore, there should be another reference waveform available in this area to apply to the group of events which show poor improvements when IRA-101-02 is applied.

- Reference waveform KAZ/249/04 yielded good Rayleigh wave improvements and poor Love wave improvements. The Rayleigh wave improvements are better than those of the previous year.

- Reference waveform PAK-028-10 yielded good Rayleigh wave improvements. Love wave improvements were poor except for the first test event, which is much closer to the reference waveform than the other three test events.

- Reference waveform PIP-039-03 yielded poor Love wave but excellent Rayleigh wave improvements with the exception of the last test event.

Thus, with the exception of reference waveform KAM*206*03, reference waveform matched filtering yields good SNNR improvements (> 3 dB) on at least one surface wave propagation mode.

The effect of reference waveform-test event separation upon SNNR improvement is illustrated by Figure V-2. A straight line least-mean-square-error fit to the data points and the 95 per cent confidence limits for this fit are shown. The plot indicates that the SNNR improvement obtained by the reference waveform matched filters decreases gradually with increasing reference waveform-test event separation. The fitted line has a slope of -3 dB per 1000 km of separation.

A measure of the variation in SNNR improvement among test events for a given reference waveform matched filter is the standard deviation of the improvement, which is also listed in Table V-2 under the mean SNNR improvement values for each reference waveform. The standard deviations of the event groups are generally rather large, having values comparable to, or in some cases greater than, the mean values. This indicates that, for most of the event groups, the idea of an "average" improvement may be meaningless. Since the primary reason for computing an average improvement is to obtain a correction factor for the apparent surface wave magnitude of an event detected by a matched filter, an event group with a large standard deviation in improvement may produce an erroneous magnitude estimate. For example, the two-standard-deviation uncertainty in Love wave magnitude for Kamchatka events matched filtered by KUR-063-23 is $\pm$ 0.3 magnitude units.

The effectiveness of reference waveform matched filters was estimated (using 1972 LR-V data) by computing the percentage of SNNR

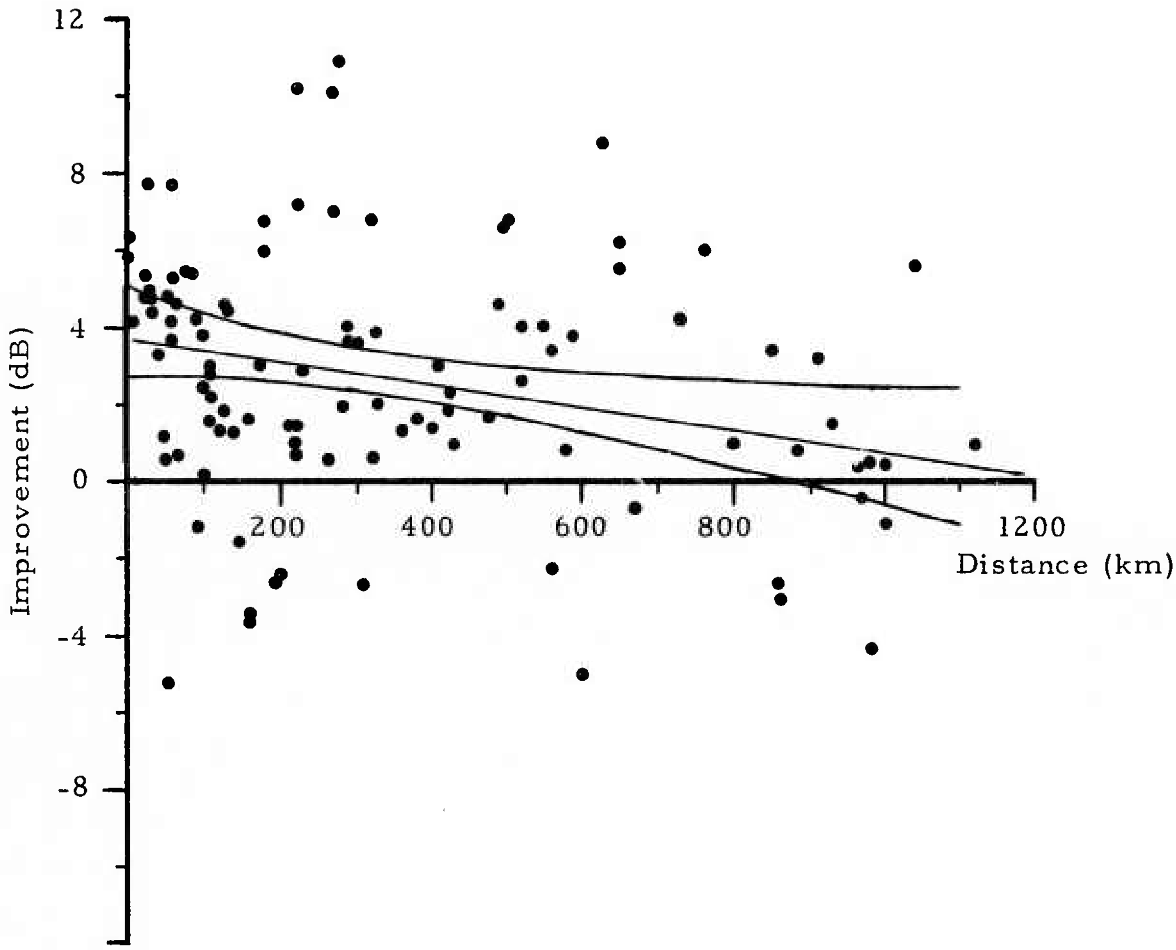



FIGURE V-2

REFERENCE WAVEFORM MATCHED FILTER IMPROVEMENT VS. REFERENCE WAVEFORM/TEST EVENT SEPARATION (VERTICAL COMPONENT) improvements less than 0 dB, between 0 and 2 dB, etc. These percentages are: 20% of the improvements were less than 0 dB, 30% were between 0 and 2 dB, 20% were between 2 and 4 dB, 15% were between 4 and 6 dB, 9% were between 6 and 8 dB, and 6% were greater than 8 dB. Therefore, even though the standard deviations are so large as to render "average" SNNR improvement values almost meaningless, it is possible to say that the probability that the output trace of a reference waveform matched filter will show a positive SNNR improvement is 0.80 and the probability that the improvement will be between 2 and 8 dB is approximately 0.45. Thus, for approximately half of the events to which reference waveform matched filters are applied, the SNNR improvement will be large enough to aid detection studies.

## C. CHIRP FILTER RESULTS

Linear chirp matched filters were applied to the beamsteered signal outputs of 76 of the events which were used in the reference waveform matched filter evaluation. These chirp filters were specified and applied in the frequency domain, using a chirp bandpass of 0.025 to 0.055 Hz. After application of these chirp filters, the data were inverse-transformed to obtain time domain chirp filter outputs.

The chirp filter response function is:

$$G(K) = e^{i2\pi(C/N)(K - K_0)^2} \qquad \text{if } K_L \leq K \leq K_H$$

$$= 0 \qquad \text{if } 0 \leq K \leq K_L \text{ or } K_H \leq K \leq N/2$$

$$G(-K) = G(K)^*$$

where: $K$ is the discrete Fourier transform frequency index

$K_L$ and $K_H$ are the lowest and highest frequencies in the passband

$K_0$ is the frequency index at which zero phase shift occurs

N is the number of transform points

C is a parameter which controls the length of the corresponding time domain waveform.

This yields a dispersive time domain waveform with a linear group delay and essentially flat amplitude at all periods in the band corresponding to $K_L \leq K \leq K_H$ (Harley, 1971).

Five chirps were applied to each test event. Their lengths were centered about the assumed optimum length and differed by increments of $\pm$ 50 seconds. The assumed optimum length was, in each case, picked from the plots of chirp length vs. distance as presented in the report of the preceding year (Heiting, et al, 1972). The SNNR improvement for the test event was then measured from the best, in terms of amplitude and shape, of the five chirp responses.

Table V-3 presents the chirp filter SNNR improvement in dB over the equivalent bandpass filter of these 76 events. The mean SNNR improvements and corresponding standard deviations are also listed for each region.

Considering those regions which contained four or more test events (three in the case of EKZ), the following comments on chirp matched filter results can be made.

- KAM - SNNR improvements were fair on all three components. The Rayleigh wave improvements are slightly better than the Love wave improvements.

- CA and CSP - SNNR improvements were poor on Love waves and fair on Rayleigh waves.

- SIR - SNNR improvements were fair on Love waves and good on Rayleigh waves.

TABLE V-3

CHIRP FILTER IMPROVEMENTS
(PAGE 1 OF 3)

| Event Designation | Region | dB SNNR Improvement Over Equivalent Bandpass Filter (.025 - .055 Hz) | | |
|---|---|---|---|---|
| | | T | V | R |
| KOM-153-21TD | KAM | -0.9 | -0.3 | 4.1 |
| KUR-154-01AL | KAM | 0.7 | 0.8 | 1.3 |
| KAM-156-07AL | KAM | -0.1 | 2.3 | -0.3 |
| KAM-157-04AL | KAM | 2.1 | 3.9 | 2.4 |
| KAM-158-10AL | KAM | 0.0 | 7.8 | 4.7 |
| KAM-165-04AL | KAM | 0.2 | 1.0 | -0.4 |
| KAM-168-09AL | KAM | 3.6 | 3.7 | 2.3 |
| KAM-173-00QC | KAM | 0.6 | -0.1 | 0.5 |
| KAM-173-10QC | KAM | 2.2 | 1.8 | 2.6 |
| KAM-177-17AL | KAM | 2.6 | 2.5 | 0.3 |
| KAM-179-06AL | KAM | 0.9 | 3.5 | 2.3 |
| KOM-180-04AL | KAM | 2.0 | 5.5 | 6.5 |
| KAM-180-14AL | KAM | 5.2 | 0.0 | 2.1 |
| KOM-183-02AL | KAM | 1.2 | 4.0 | 6.4 |
| KAM-186-13AL | KAM | 4.6 | -0.2 | 2.7 |
| KAM-192-12AL | KAM | -0.2 | -1.5 | 0.0 |
| KAM-193-08QC | KAM | 2.9 | 1.9 | 1.9 |
| KUR-194-00QC | KAM | 4.4 | 6.4 | 5.2 |
| KAM-199-08AL | KAM | 1.4 | 1.8 | 1.6 |
| KUR-209-00AL | KAM | 0.6 | 3.0 | 3.4 |
| KUR-216-02QC | KAM | 1.1 | 3.7 | 1.8 |
| KUR-218-22AL | KAM | 4.0 | 6.0 | 1.7 |
| KOM-229-10QC | KAM | 3.0 | 3.4 | 3.7 |
| KAM-229-21AL | KAM | 1.7 | 0.7 | 2.1 |
| KAM-231-19AL | KAM | 4.7 | 2.5 | 3.2 |
| KAM-233-08AL | KAM | 2.7 | 0.3 | 0.1 |
| KUR-235-14AL | KAM | 5.7 | 4.7 | 4.8 |
| Mean Improvements for Kamchatka | | 2.1 | 2.6 | 2.5 |
| Standard Deviation | | 1.8 | 2.2 | 1.9 |
| KUR-232-23AL | KUR | 1.1 | 5.5 | 3.4 |
| SIN-154-06AL | CA | 2.3 | 4.2 | 5.0 |
| TSI-154-16AL | CA | -0.3 | 0.4 | 2.0 |
| TIB-170-04AL | CA | -1.3 | -0.7 | 1.0 |

TABLE V-3

CHIRP FILTER IMPROVEMENTS
(PAGE 2 OF 3)

| Event Designation | Region | dB SNNR Improvement Over Equivalent Bandpass Filter (.025 - .055 Hz) T | V | R |
|---|---|---|---|---|
| HIN-178-20AL | CA | 2.3 | 4.2 | 1.6 |
| TSI-180-03AL | CA | 2.4 | 1.4 | 3.1 |
| AUB-181-03QC | CA | 2.5 | -2.4 | -1.9 |
| SIN-187-01AL | CA | -1.1 | 4.2 | 4.1 |
| SIN-187-04AL | CA | 2.8 | 0.2 | -0.1 |
| SIN-192-19AL | CA | -1.9 | 2.8 | 1.5 |
| KTB-206-14AL | CA | 3.8 | 0.6 | -0.8 |
| AFG-211-17AL | CA | 3.8 | 2.1 | 4.0 |
| Mean Improvements for Central Asia | | 1.4 | 1.5 | 1.8 |
| Standard Deviation | | 2.1 | 2.2 | 2.2 |
| IIQ-164-13AL | CSP | -1.3 | 1.6 | 1.5 |
| IIQ-165-00AL | CSP | -1.8 | 1.1 | 1.3 |
| IIQ-166-04AL | CSP | 0.2 | -0.1 | 0.1 |
| IIQ-175-08AL | CSP | 1.9 | 1.2 | 2.3 |
| IRA-202-13AL | CSP | 0.0 | 4.4 | 4.2 |
| Mean Improvements for Caspian Sea | | -0.2 | 1.6 | 1.9 |
| Standard Deviation | | 1.4 | 1.6 | 1.5 |
| IRA-155-08AL | SIR | 1.4 | -0.5 | 0.1 |
| IRA-182-17QC | SIR | 2.8 | 4.7 | 4.7 |
| IRA-184-12AL | SIR | 0.0 | 4.2 | 3.3 |
| IRA-187-16AL | SIR | -1.1 | 4.9 | 7.3 |
| IRA-196-13QC | SIR | 3.0 | 3.6 | 5.0 |
| IRA-216-22AL | SIR | 4.5 | 5.7 | 4.5 |
| Mean Improvements for Southern Iran | | 1.8 | 3.8 | 4.2 |
| Standard Deviation | | 2.1 | 2.2 | 2.4 |
| MED-187-18AL | GT | 2.2 | 2.0 | 2.5 |
| TUR-216-21AL | GT | 0.5 | 2.6 | 2.3 |
| YUG-243-00AL | GT | 0.4 | 2.4 | 0.2 |
| RYU-155-02AL | TWN | 2.4 | 3.0 | 1.3 |
| TWN-160-09AL | TWN | 4.5 | 2.0 | 3.5 |
| TWN-178-08QC | TWN | 4.2 | 6.1 | 6.2 |

TABLE V-3

CHIRP FILTER IMPROVEMENTS
(PAGE 3 OF 3)

| Event Designation | Region | dB SNNR Improvement Over Equivalent Bandpass Filter (.025 - .055 Hz) | | |
|---|---|---|---|---|
| | | T | V | R |
| TWN-182-18TD | TWN | 2.1 | 6.7 | 5.6 |
| RYU-197-02AL | TWN | 2.9 | 4.3 | 5.3 |
| TWN-198-13AL | TWN | 3.4 | 3.8 | 2.5 |
| TWN-212-16AL | TWN | 1.0 | 4.8 | 5.5 |
| Mean Improvement for Taiwan Region | | 2.9 | 4.4 | 4.3 |
| Standard Deviation | | 1.2 | 1.7 | 1.8 |
| EKZ-159-01QD | Eastern Kazakh* | 4.6 | 4.1 | 6.1 |
| EKZ-307-01AL | Eastern Kazakh* | 0.6 | 5.4 | 5.5 |
| EKZ-345-04AL | Eastern Kazakh* | 2.5 | 6.8 | 6.5 |
| Mean Improvement for Eastern Kazkah | | 2.6 | 5.4 | 6.0 |
| Standard Deviation | | 2.0 | 1.4 | 0.5 |
| NVZ-241-05AL | Novaya Zemlya* | 4.5 | 8.5 | 7.1 |
| TSI-156-23AL | Tsinghai Prov. | 2.0 | 0.0 | 0.8 |
| ERS-165-10QD | Eastern Russia | 0.6 | 5.3 | 0.9 |
| TIB-198-02AL | Tibet | -2.0 | -0.3 | -2.1 |
| RYU-209-16AL | Ryukyu Islands | 3.5 | 7.3 | 6.9 |
| KUR-211-21AL | Kurile Islands | 2.9 | 2.0 | 1.8 |
| IRA-221-19AL | Eastern Iran | -3.1 | 3.9 | 3.7 |
| ERS-222-20AL | Eastern Russia | 2.0 | 4.3 | 6.0 |
| SIB-238-04AL | Siberia | 1.9 | 4.5 | 3.8 |
| TSI-243-15AL | Tsinghai Prov. | 0.1 | -0.5 | 2.9 |
| CRS-244-14AL | Central Russia | 2.0 | 1.1 | 2.0 |
| PAK-162-11AL | South Pakistan | 1.9 | 4.8 | 4.1 |
| PAK-179-06QC | South Pakistan | 3.1 | 4.4 | 4.6 |
| PAK-179-10AL | South Pakistan | 4.3 | 5.0 | 3.9 |

* = Test Area

- TWN - SNNR improvements were good on all three components. The Rayleigh wave improvements were better than the Love wave improvements.

- EKZ - SNNR improvements were good on Love waves and excellent on Rayleigh waves.

In general, chirp filter Rayleigh wave SNNR improvements were better than Love wave improvements.

The standard deviation values for each of the mean SNNR improvements indicate there is considerable variation in the SNNR improvements yielded by chirp matched filters. For example, the two events KAM-173-00QC and KAM-180-14AL have SNNR improvements as measured on LQ-T differing by more than 4 dB. A possible explanation for this is that the two events had different source mechanisms.

The chirp length data is summarized in Figures V-3, V-4 and V-5 for the transverse, vertical, and radial components respectively. The chirp lengths plotted are the chirp lengths giving the best improvements. The corresponding distances are great circle distances in kilometers between event epicenter and the ALPA array. The chirp lengths applied to presumed explosions are indicated by open circles while those applied to earthquakes are indicated by dots. A least-mean-square-error fit was made for the data points of each plot. The dotted lines 100 seconds above and 100 seconds below this line represent the range in chirp lengths which would be used if five chirps were applied to an event, the chirp length increment was 50 seconds, and the center chirp length was picked from the least-mean-square-error fit.

For each component, 70 percent or more of the data points fall within the 100 second bounds. This implies that the least-mean-square-error fit can be used to obtain a good first estimate of the optimum chirp length to apply to a given event. The range in epicentral distance for each region is

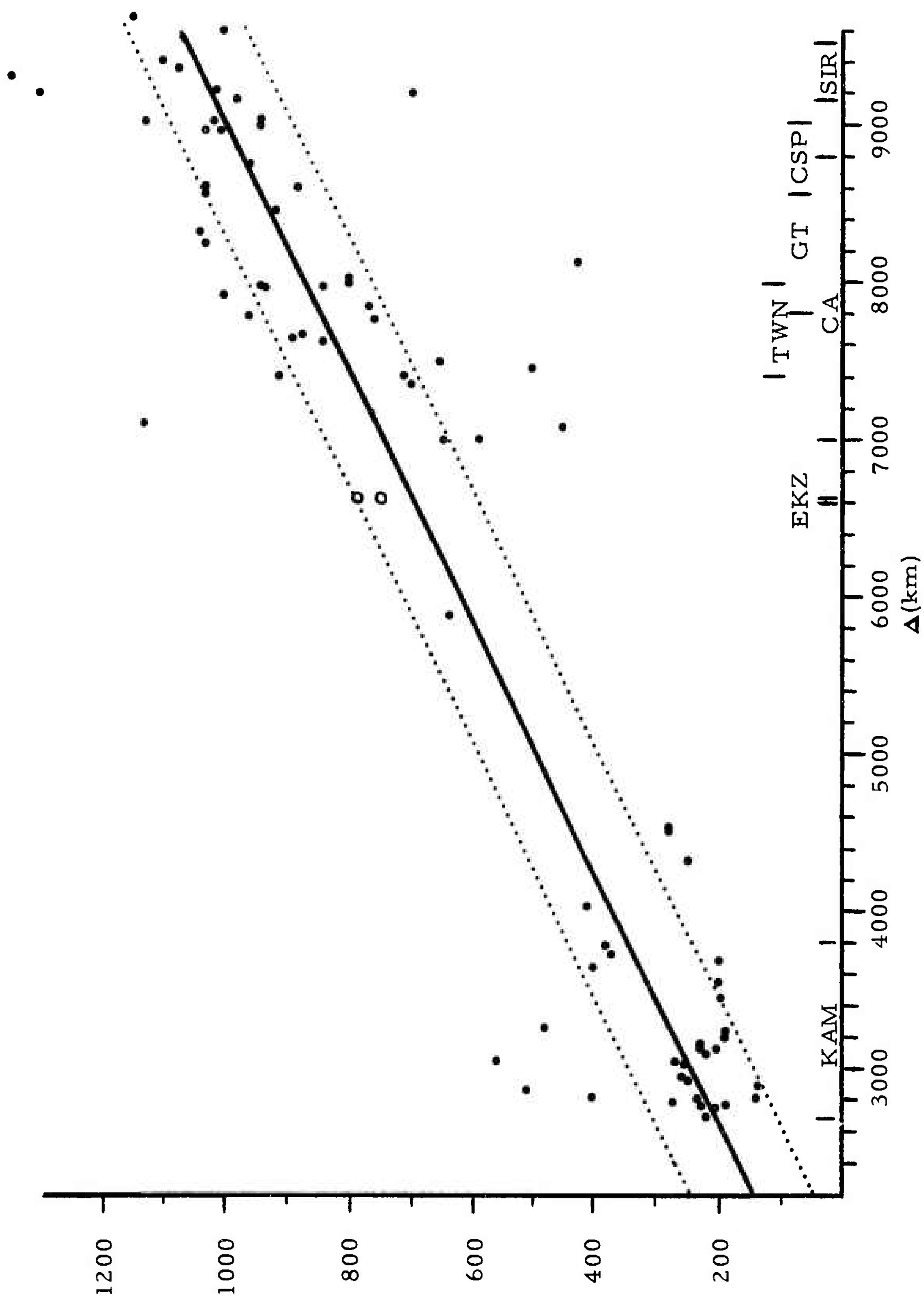



FIGURE V-3
CHIRP FILTER LENGTH VS. DISTANCE (TRANSVERSE COMPONENT)

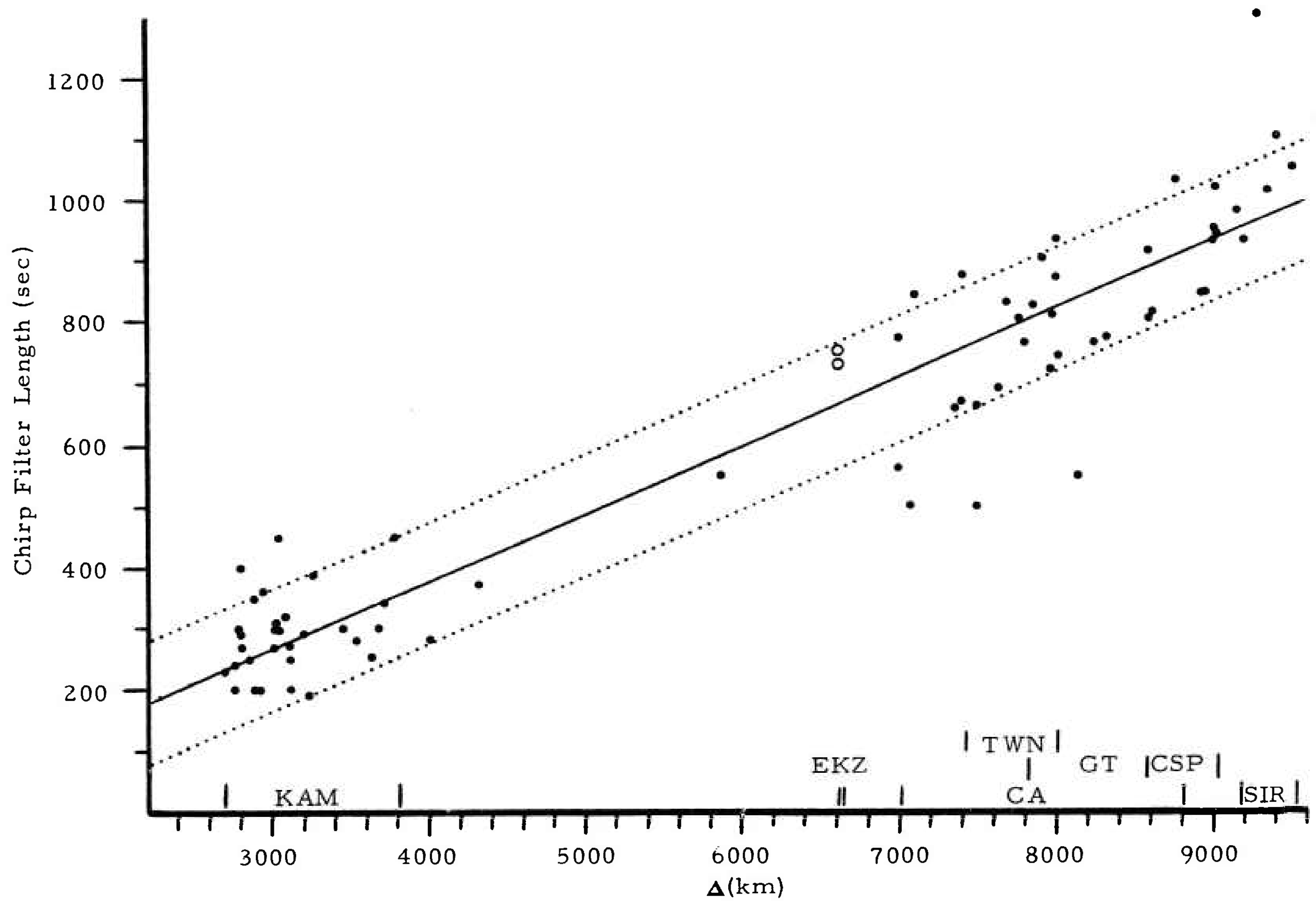



FIGURE V-4

CHIRP FILTER LENGTH VS. DISTANCE (VERTICAL COMPONENT)

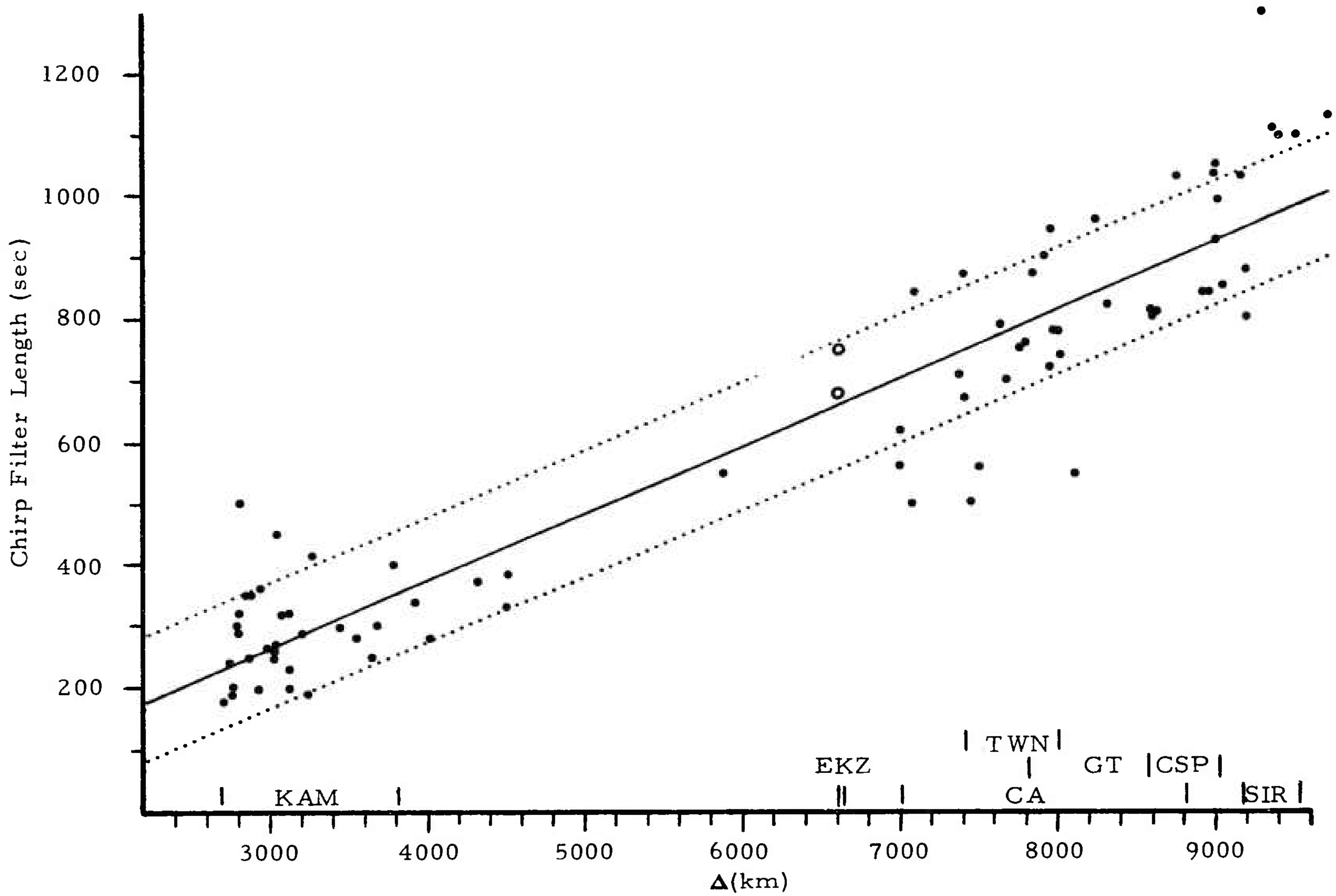



FIGURE V-5

CHIRP FILTER LENGTH VS. DISTANCE (RADIAL COMPONENT) shown on Figures V-3, V-4, and V-5 to indicate the dominant data source for each such range.

An estimate of the effectiveness of chirp filters was made (using LR-V data) by computing the percentage of SNNR improvements less than 0 dB, between 0 and 2 dB, etc. These percentages are: 15% of the improvements were less than 0 dB, 21% were between 0 and 2dB, 24% were between 2 and 4 dB, 30% were between 4 and 6 dB, 9% were between 6 and 8 dB, and 1% were greater than 8 dB. Thus it is possible to say that the probability that the output trace of a chirp matched filter will show a positive improvement is 0.85 and the probability that the improvement will be between 2 and 8 dB is approximately 0.6 . Therefore, for better than half of the test events to which chirp filters are applied, the SNNR improvements will be large enough to aid detection studies.

## D. COMPARISON OF REFERENCE WAVEFORM AND CHIRP MATCHED FILTER RESULTS

Those regions containing four or more test events (three in the case of EKZ) were selected to compare reference waveform and chirp matched filter results on a regional basis. The mean SNNR improvements and corresponding standard deviations are presented in Table V-4 for these two types of filtering. For each region, the computations were made on identical sets of test events. The criteria for stating that one type of filtering performed better than the other was that the better filter showed a higher mean improvement and a lower standard deviation of the improvement. No judgement was made in cases where one filtering type had the higher mean and the other had the lower standard deviation.

The results of this are summarized as follows:

- KAM - Chirp filters performed better than reference waveform filters on the vertical and radial Rayleigh waves.

TABLE V-4

COMPARISON OF REFERENCE WAVEFORM AND CHIRP FILTER SNNR IMPROVEMENTS

| Region | Type of Filter | Transverse | | Vertical | | Radial | |
|---|---|---|---|---|---|---|---|
| | | Mean | Standard Deviation | Mean | Standard Deviation | Mean | Standard Deviation |
| KAM | RMF | 2.5 | 2.8 | 1.5 | 3.4 | 1.3 | 2.7 |
| | CMF | 2.1 | 1.8 | 2.6 | 2.2 | 2.5 | 1.9 |
| CA | RMF | 1.1 | 2.7 | 0.9 | 3.3 | 1.2 | 2.6 |
| | CMF | 1.4 | 2.1 | 1.5 | 2.2 | 1.8 | 2.2 |
| EKZ | RMF | 1.3 | 2.8 | 5.9 | 0.5 | 4.9 | 0.9 |
| | CMF | 2.6 | 2.0 | 5.4 | 1.4 | 6.0 | 0.5 |
| TWN | RMF | 0.0 | 1.3 | 6.6 | 3.3 | 6.8 | 4.2 |
| | CMF | 2.6 | 1.5 | 3.7 | 2.5 | 3.6 | 2.4 |
| CSP | RMF | 1.1 | 3.4 | 0.3 | 4.0 | 2.3 | 4.1 |
| | CMF | -0.2 | 1.4 | 1.6 | 1.6 | 1.9 | 1.5 |
| SIR | RMF | 1.2 | 2.4 | 2.7 | 3.9 | 3.0 | 3.5 |
| | CMF | 1.8 | 2.1 | 3.8 | 2.2 | 4.2 | 2.4 |

- CA - Chirp filters performed better than reference waveform filters on all three components.

- EKZ - Chirp filters performed better than reference waveforms on the Love waves. On the Rayleigh waves, chirps were better on the vertical and reference waveforms were better on the radial. Therefore, their performance on Rayleigh waves was about the same.

- TWN - The results in this region were, according to the judgement criteria, indeterminant. However, on the Rayleigh wave mean improvements for reference waveforms are almost double those of the chirps, and so the reference waveforms are considered to be better.

- CSP - The chirp filters performed better than the reference waveforms on the vertical Rayleigh wave.

- SIR - The chirp filters performed better than the reference waveforms on all three components.

The overall relative performance of chirp and reference waveform matched filters is illustrated by Figure V-6. This figure indicates that 57% of the test events showed higher chirp SNNR improvements than reference waveform improvements.

One other comparison between chirp and reference waveform matched filter performance is that the probability that a matched filter will yield a SNNR improvement of between 2 and 8 dB is 0.45 for reference waveforms and 0.60 for chirps. Thus, it is concluded that chirp matched filters perform slightly better than reference waveform matched filters.

As presently conducted, matched filtering is fulfilling the goal of increasing the ALPA detection capability but not the goal of providing stable

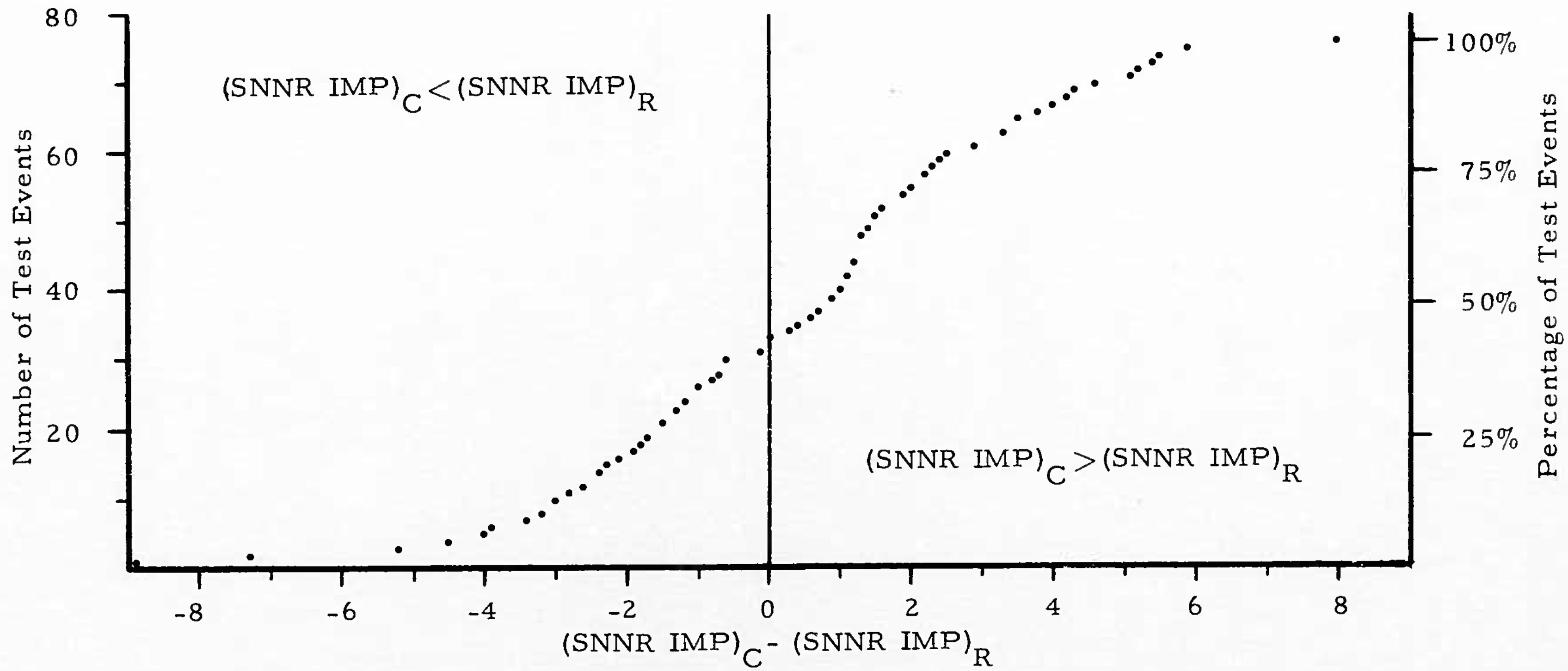



FIGURE V-6

CUMULATIVE DISTRIBUTION OF CHIRP SNNR IMPROVEMENT MINUS REFERENCE WAVEFORM SNNR IMPROVEMENT (VERTICAL COMPONENT) estimates of SNNR improvement to permit the computation of the surface-wave magnitude of an event detected only by a matched filter. Inspection of Appendix A reveals that of 128 events from 1972 not detected on the bandpass-filtered beam, 26 (20%) were detected by either a reference waveform or a chirp matched filter. Considering the 1972 Eurasian events and the 1972 Kurile Islands - Kamchatka events separately, it was found that inclusion of the matched-filter detections did not change the 90% detection thresholds but did change the 50% detection thresholds by 0.3 magnitude units for Eurasian data and 0.4 magnitude units for the Kurile Islands - Kamchatka data.

As previously described in this section, the standard deviations of the SNNR improvements are so large that the use of an "average" SNNR improvement to compute a surface-wave magnitude is not very meaningful. Therefore, techniques for making such magnitude estimates from matched filter outputs should be revised, since detections made on matched filter outputs occur only when the match is good, it appears that using a high-side estimate of the average improvement (e.g., twice the mean or the mean plus one standard deviation) would give a better surface-wave magnitude value. For the representative case of 3 dB average SNNR improvement and 3 dB variance, this would mean that a factor of 2 should be used to get the surface-wave magnitude estimate instead of a factor of 1.4, which would lower the surface-wave magnitude estimate by 0.1 units.

## SECTION VI
## S-WAVE PROCESSING RESULTS

### A. INTRODUCTION

S-wave processing was performed on the Kurile Islands - Kamchatka earthquake population of the 1972 data base to resolve an apparent contradiction appearing in the report of the preceeding year (Heiting, et al, 1972). In that report, it was stated that the 90% probability of S-wave detection for the Kurile Islands - Kamchatka region occurred above $m_b = 5.0$. However, in the figure accompanying that report, this 90% detection level appears to be at about $m_b = 4.4$.

To resolve this problem, S-wave processing was performed on the larger population of events available from the 1972 data base. Long-period S-wave beams were formed for 103 events having epicenters in the Kurile Islands and Kamchatka regions, using the apparent horizontal S-wave velocity appropriate to each epicentral distance. The values of S-wave velocity were taken from a plot of S-wave apparent horizontal velocity as a function of epicentral distance (Texas Instruments Incorporated, 1964). Bandpass filtered (0.025 to 0.055 Hz) beams were formed for the rotated transverse, vertical, and radial components. The detection criteria were that the signal be at least 3 dB above the noise and that the signal arrived within $\pm$ 10 seconds of the predicted arrival time. The amplitude/period data were measured on the bandpass-filtered component which showed the largest S-wave amplitude.

## B. LONG-PERIOD S-WAVE DETECTION THRESHOLD ESTIMATE FOR ALPA

The histogram in the upper portion of Figure VI-1 shows the total number of events processed at each body-wave magnitude for the Kurile Islands - Kamchatka earthquake populations. These are subdivided (shaded and unshaded portions of the histogram) into summer and winter populations. The lower graph shows:

- detection percentages as a function of body-wave magnitude for the total population,
- detection percentages for the summer population,
- detection percentages for the winter population.

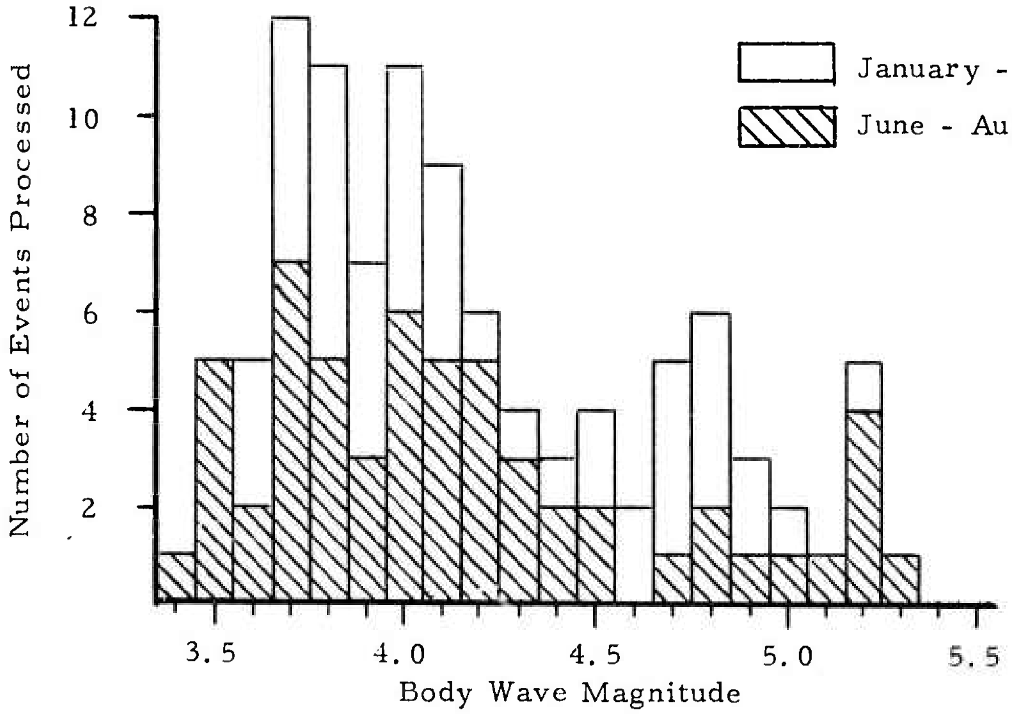
The data clearly indicates that the 90% probability of S-wave detection occurs just below $m_b = 4.5$. This also holds true for the summer and winter populations. However, it is worthy of note that a much higher percentage of summer events (30%) with $m_b$ values below 4.5 were detected than of winter events (7%). This may be attributed to the lower RMS noise level of the summer months.

## C. DISCRIMINATION BY MEANS OF LONG-PERIOD S-WAVES

The S-wave amplitude/period data for the 36 detected events are displayed in Figure VI-2. For comparison, the corresponding data for the few presumed explosions which had detected S-waves are indicated by solid triangles. The values of A/T were normalized to a body-wave magnitude of 5.0 and an epicentral distance of 20°, following the general method used by Evernden (1969). The normalization computation may be summarized as:

$$A/T \Big|_{\text{Norm.}} = \left[10^{0.013\,\Delta - m_b + 4.74}\right]\left[A/T\right]$$

(Heiting, et al, 1972)



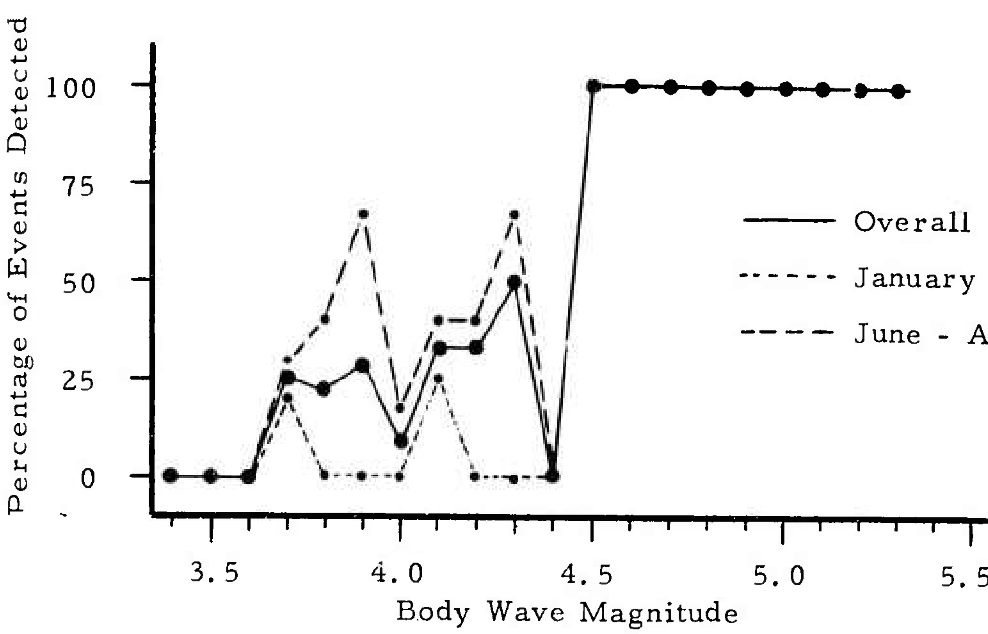




FIGURE VI-1

S-WAVE DETECTION DATA FOR KURILE ISLANDS - KAMCHATKA AREA

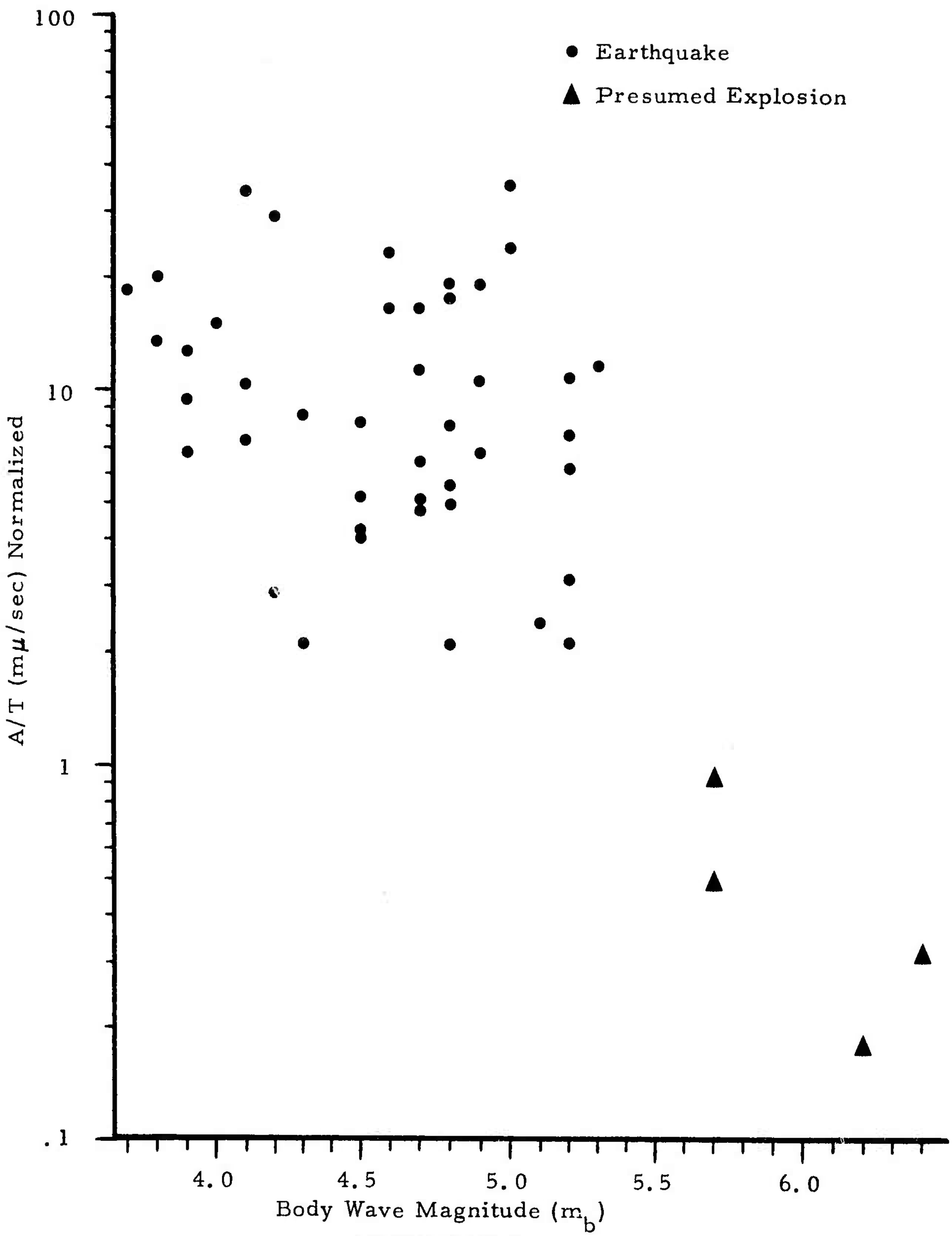



FIGURE VI-2

S-WAVE AMPLITUDE/PERIOD VS. $m_b$

The normalized data show complete separation by a factor of two between the earthquake and presumed explosion populations. Also, there is a factor of ten separation between the average A/T values of the two populations. Therefore, S-wave A/T normalized values are a good earthquake-presumed explosion discriminant for $m_b = 4.5$ or greater.

## SECTION VII

## ALPA SURFACE WAVE DETECTION CAPABILITY

Estimates of ALPA surface wave detection capability were determined for each region described in Section IV with the exception of the Taiwan region, which did not have a large enough event population. In each case, this estimate was obtained by plotting the percentage of earthquakes for which surface waves were detected as a function of body-wave magnitude. The histogram in the upper portion of each of the Figures VII-1 through VII-7 describes the portion of the 1970-1972 data base belonging to the given region. These histograms were used to compute the incremental detection probabilities which appear in the lower portion of each of the figures. The events used are designated D for detected and ND for not detected in Appendix A.

The criteria for determining whether detection was achieved for an event are:

- A peak in any output trace 3 dB above any other peak in a 20 minute time gate centered at the expected peak occurrence time.
- A peak which occurs within ± 180 seconds of the expected peak occurrence time.

It should be noted that these criteria are not absolute. Occasionally, an event was listed as detected which did not meet both of these criteria. Peaks could be less than 3 dB above other peaks in the 20 minute time gate and still be identified as signals from their dispersion characteristics. Also, some peaks, from Central Asian events in particular, appeared later than the second criterion allows, but were still recognized as signals. Although we do not have

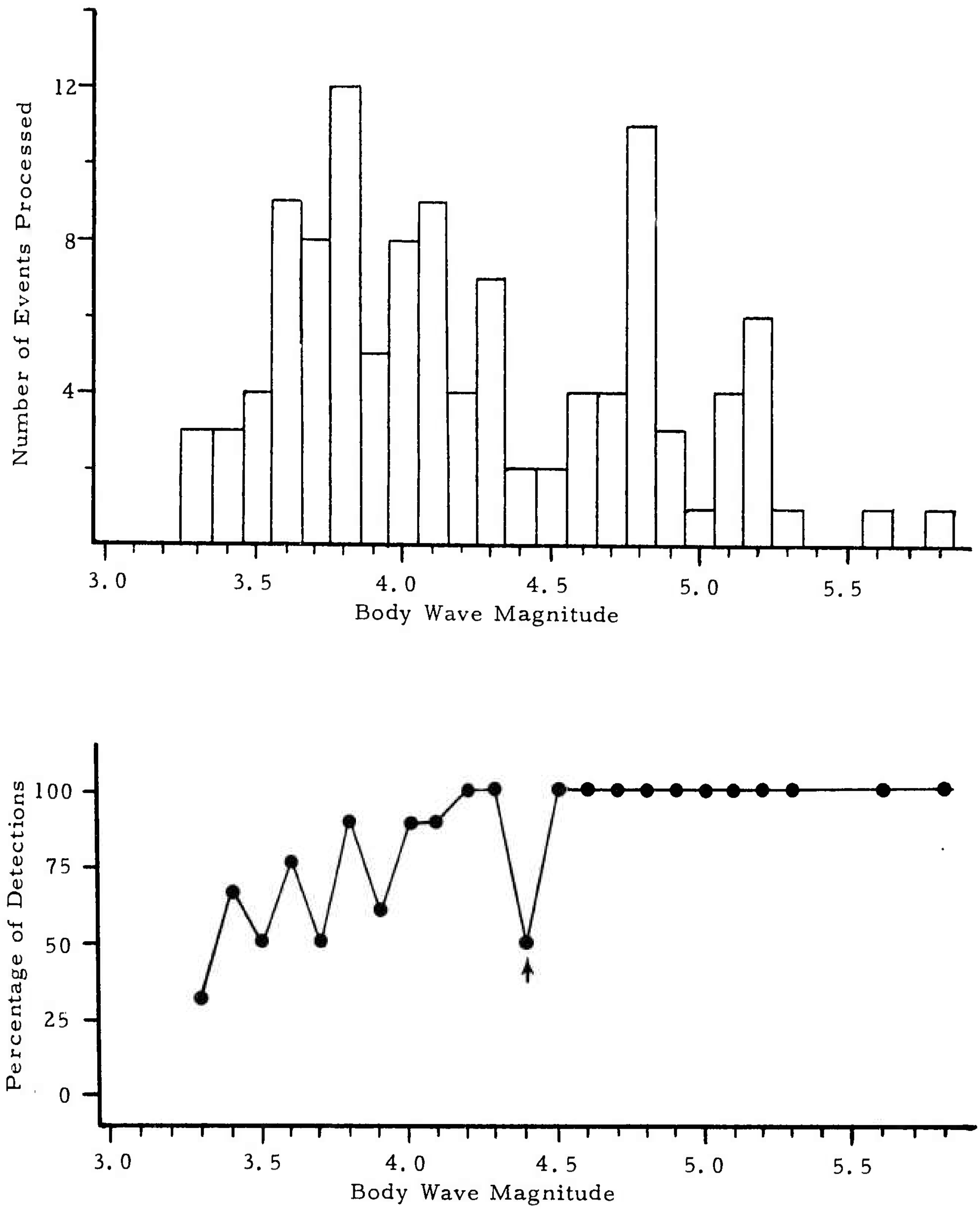
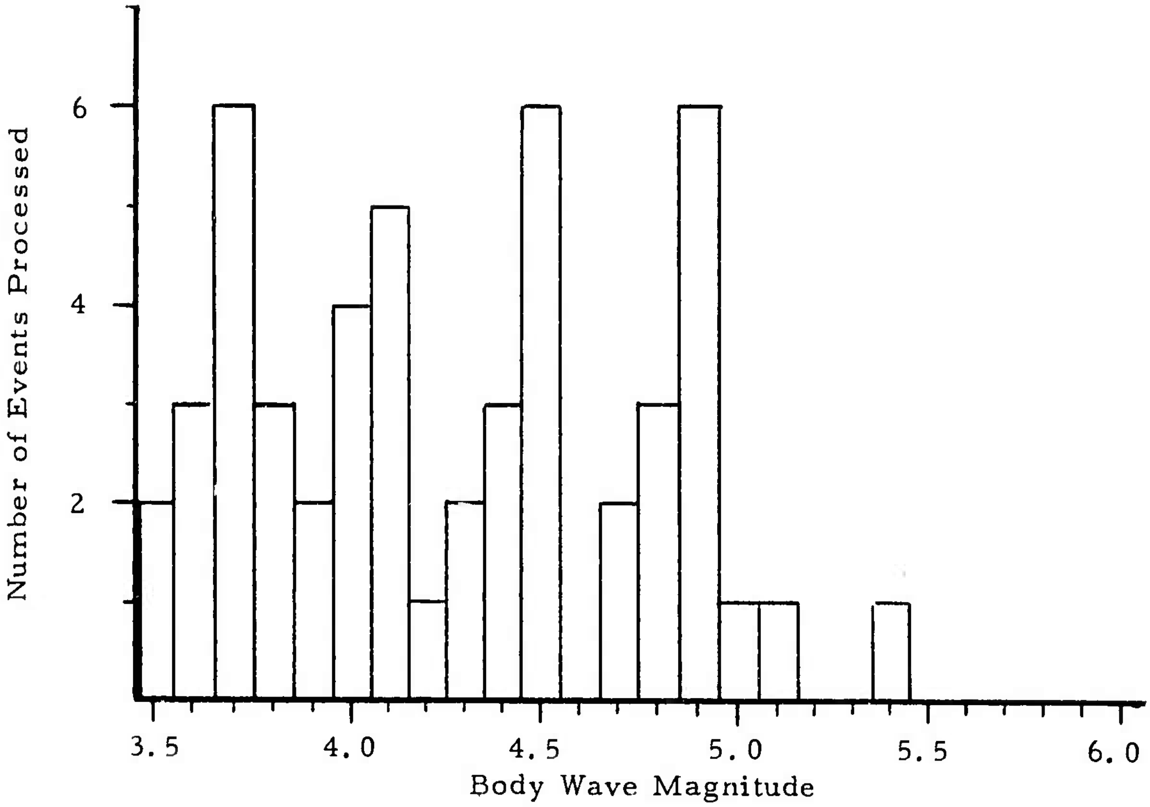



FIGURE VII-1

SURFACE WAVE DETECTION DATA FOR KAMCHATKA REGION



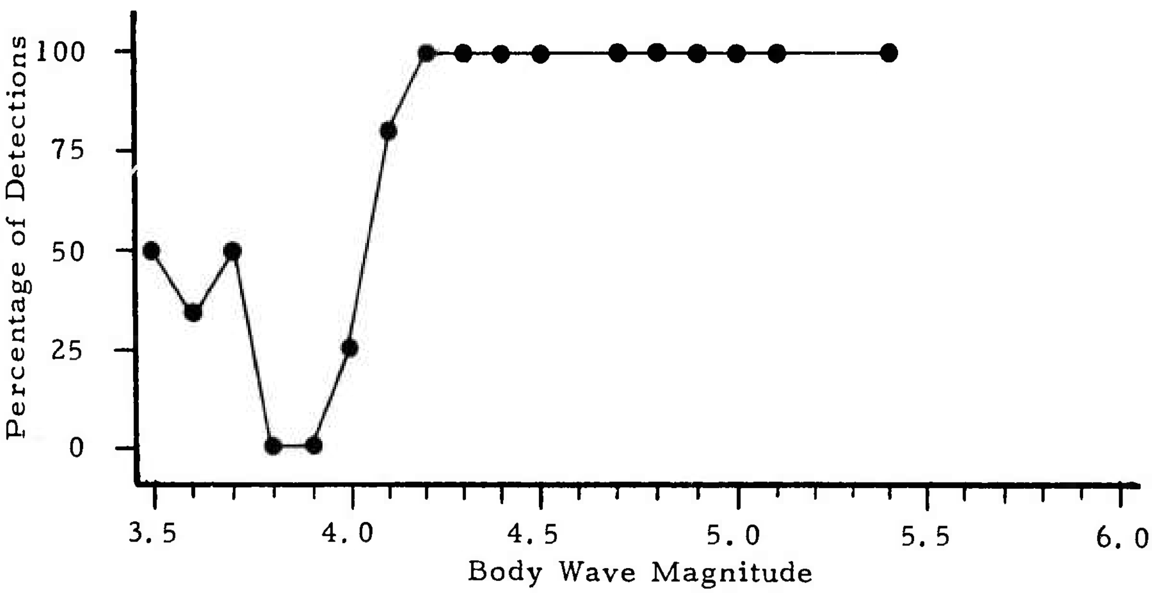




FIGURE VII-2

SURFACE WAVE DETECTION DATA FOR KURILE ISLANDS REGION

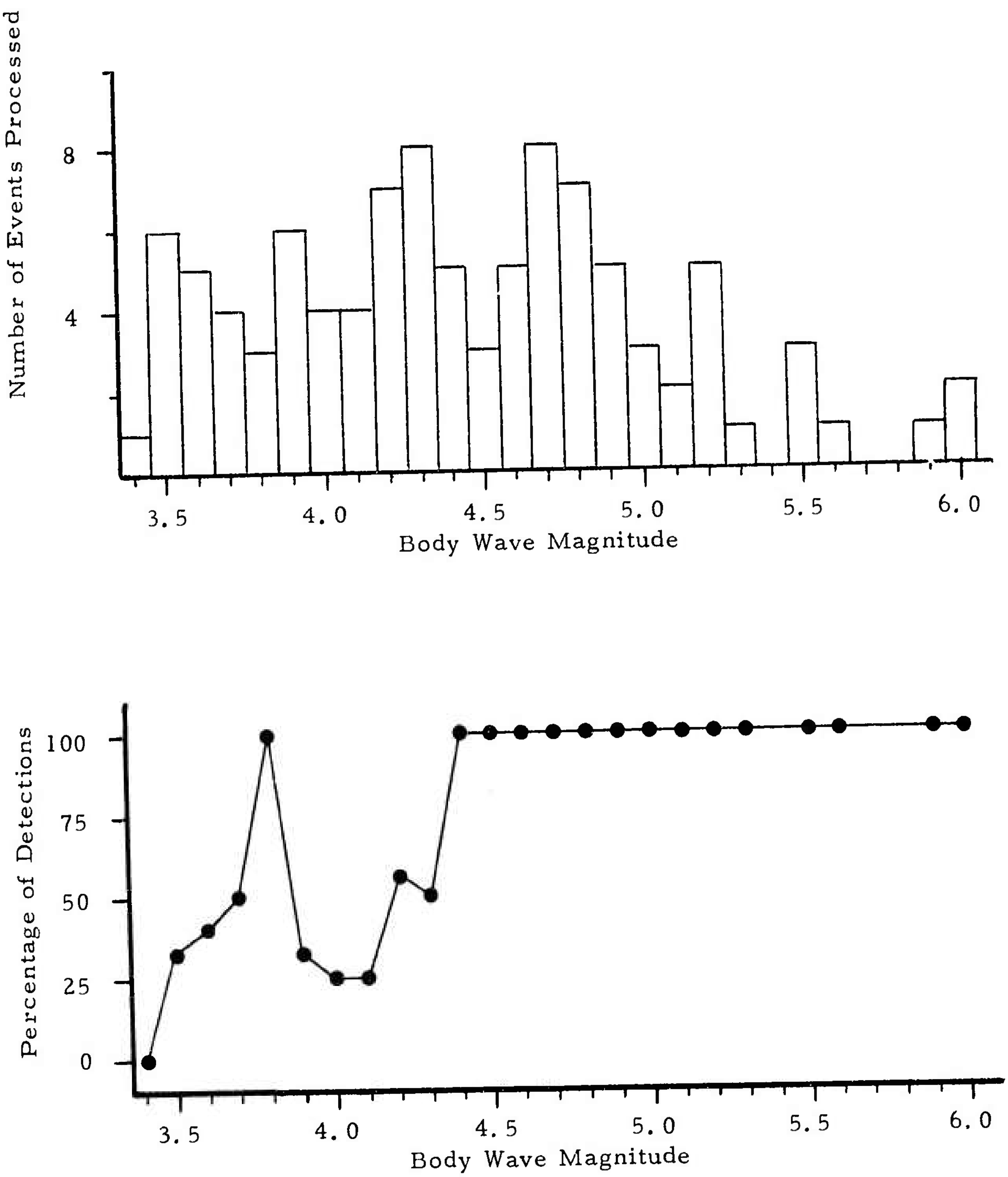
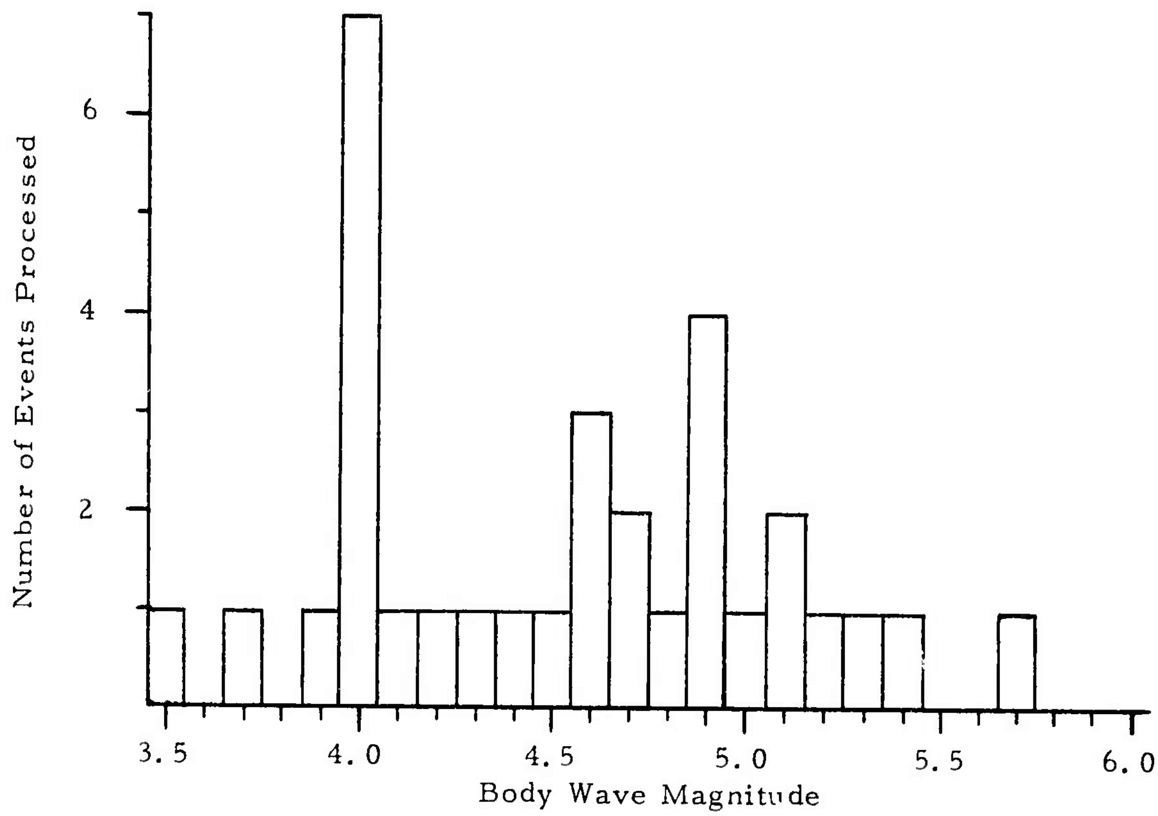



FIGURE VII-3

SURFACE WAVE DETECTION DATA FOR CENTRAL ASIA



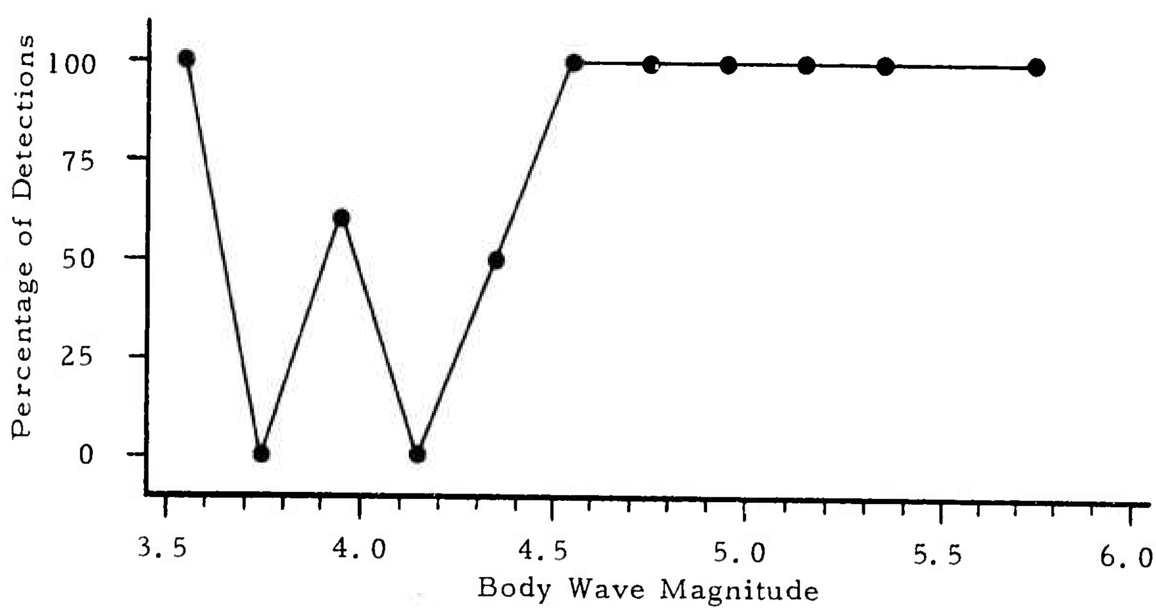




FIGURE VII-4

SURFACE WAVE DETECTION DATA FOR CASPIAN SEA REGION

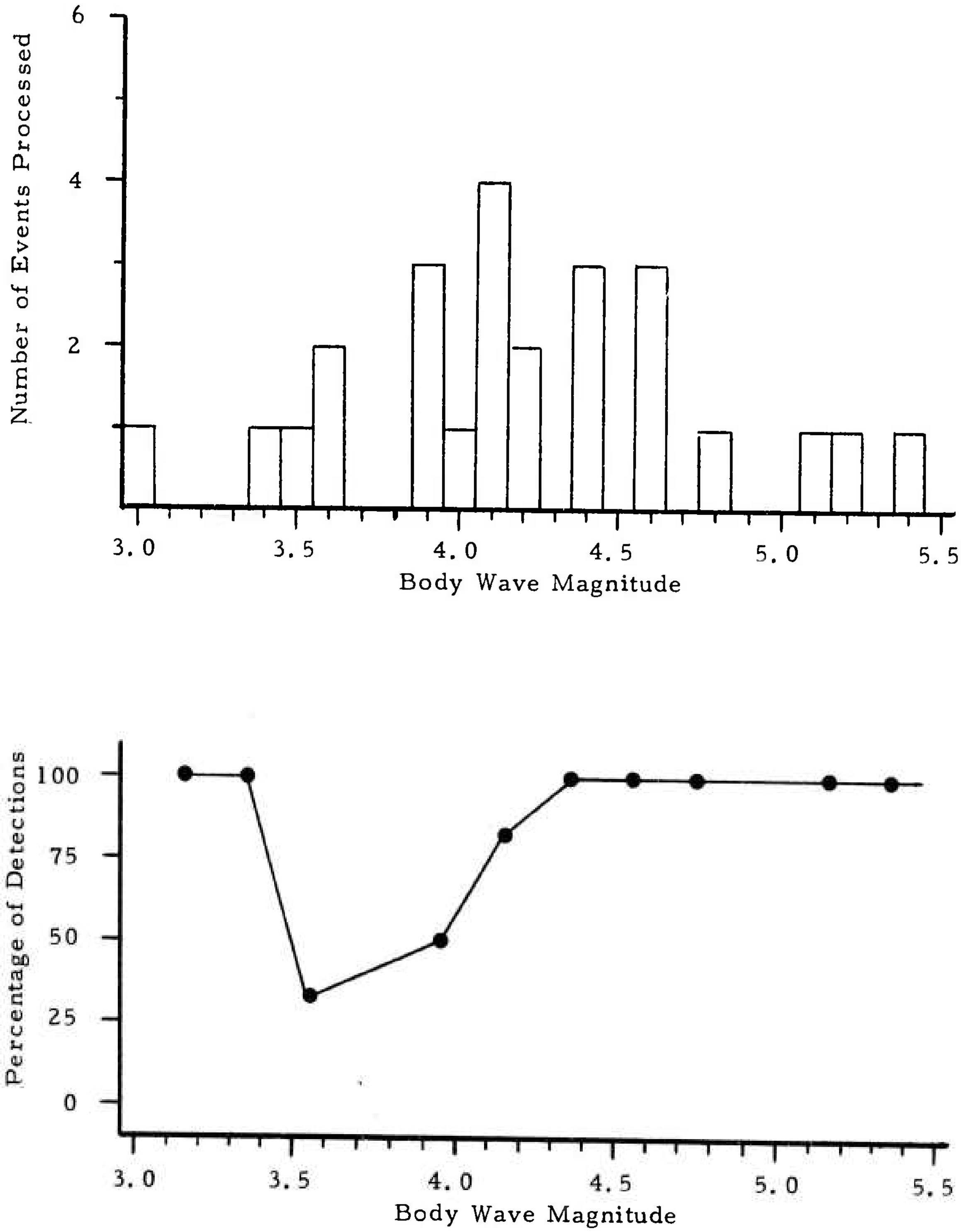
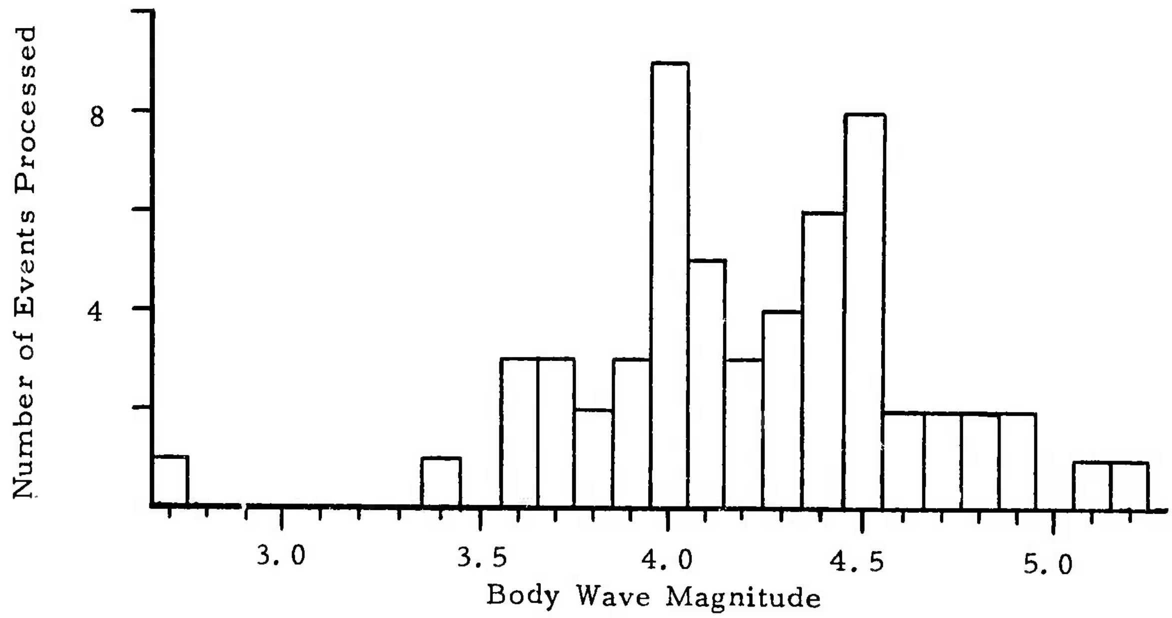



FIGURE VII-5

SURFACE WAVE DETECTION DATA FOR SOUTHERN IRAN REGION



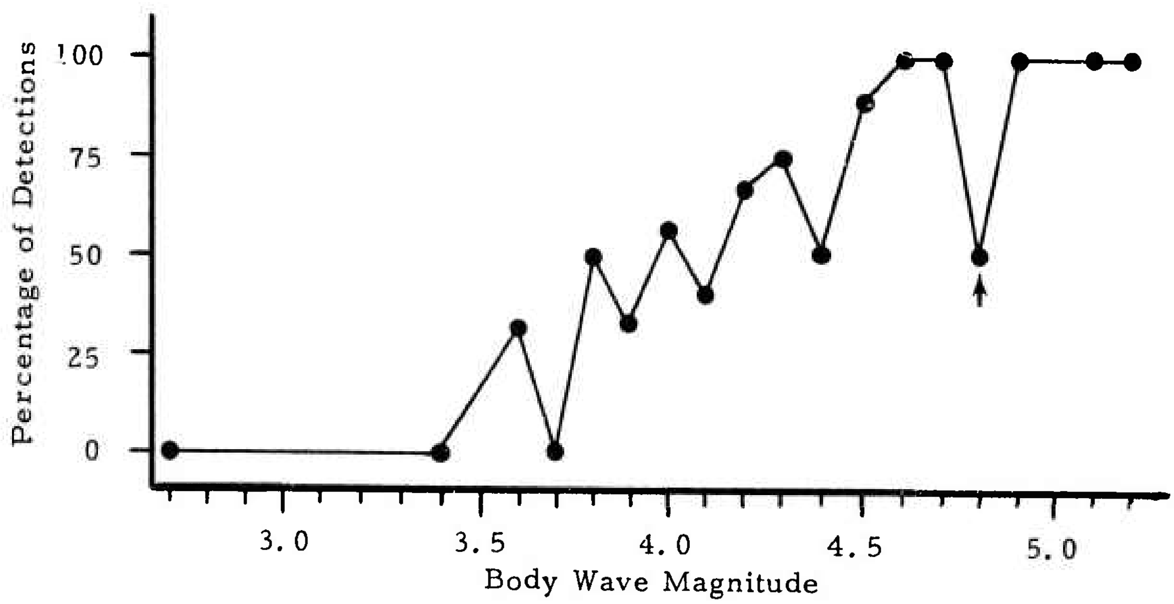
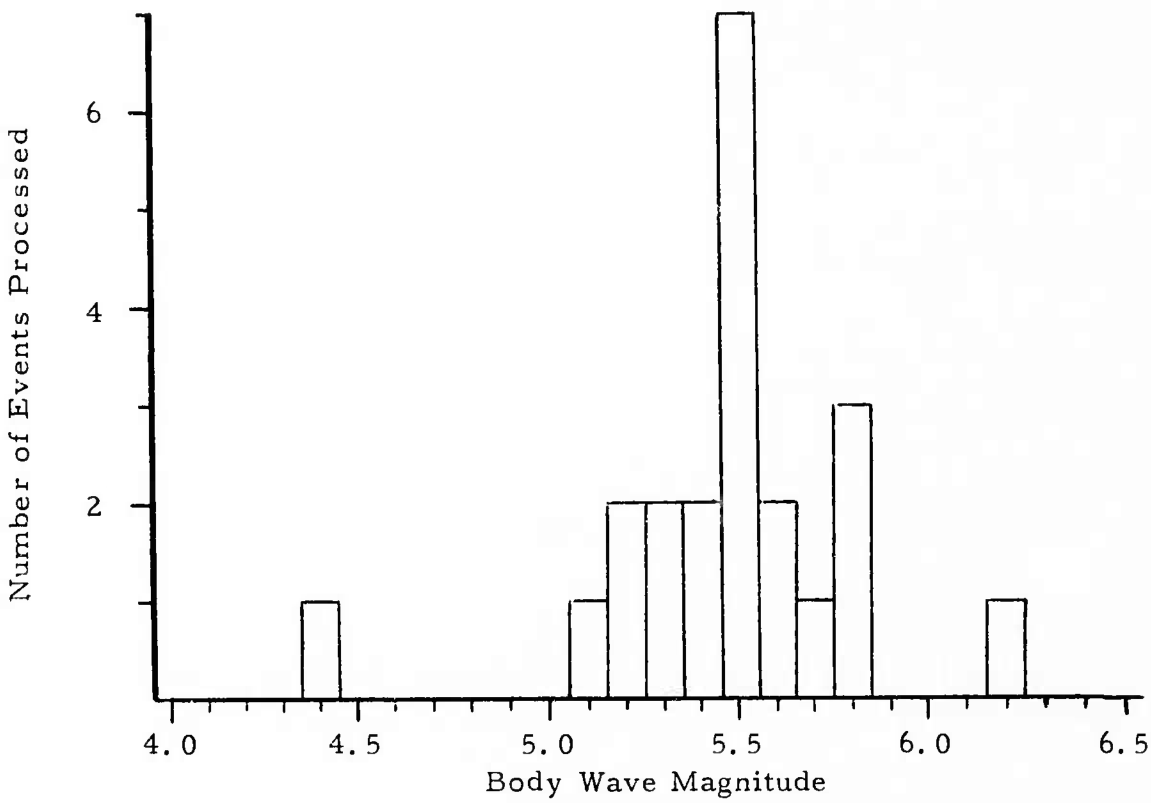




FIGURE VII-6

SURFACE WAVE DETECTION DATA FOR GREECE-TURKEY REGION



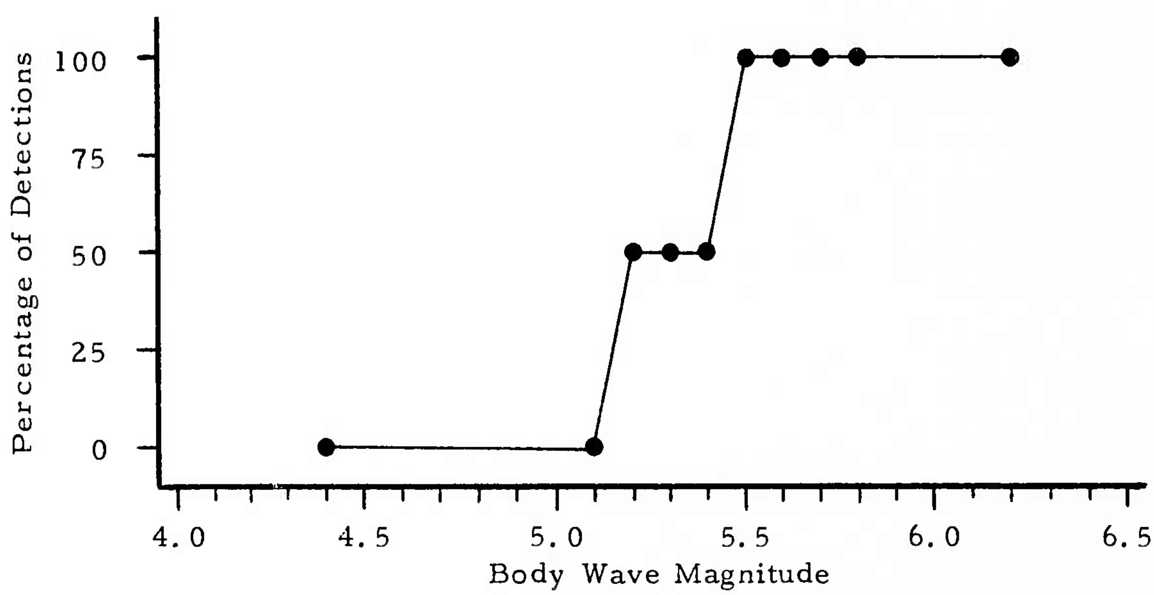




FIGURE VII-7

SURFACE WAVE DETECTION DATA FOR EASTERN KAZAKH TEST AREA a quantitative figure, we believe that the false alarm rate associated with this detection scheme is very low ($< 1\%$).

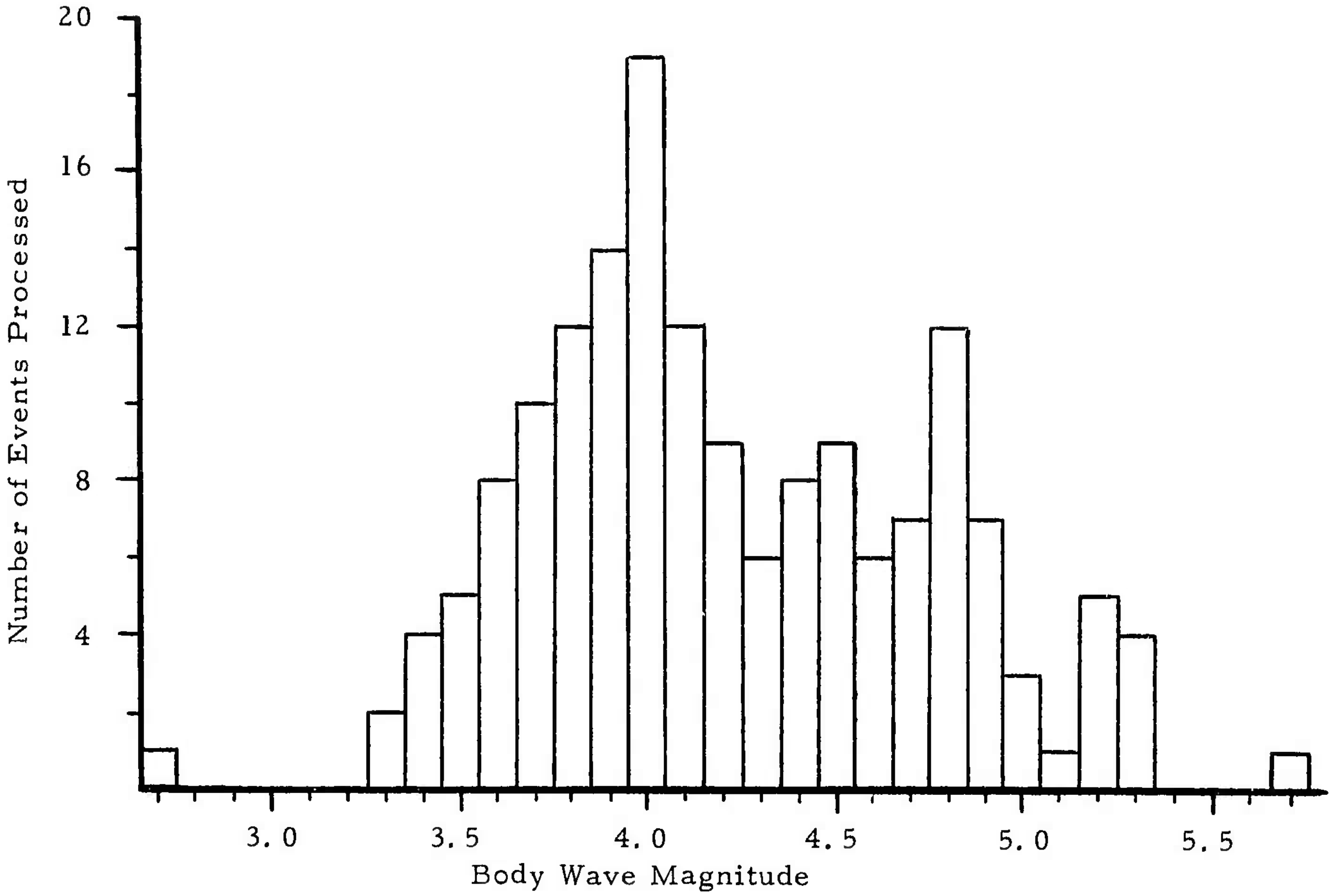
By region, the results of this analysis are:

- Kamchatka Region: The 90% detection level is at $m_b = 4.1$. The notch in the detection curve at $m_b = 4.4$ (indicated by an arrow) was not considered significant, since there are only two events at this $m_b$ increment, while there are seven at $m_b = 4.3$ and 5 at $m_b = 4.2$, all of which were detected.
- Kurile Islands Region: The 90% detection level is between $m_b = 4.1$ and $m_b = 4.2$.
- Central Asia Region: The 90% detection level is just below $m_b = 4.4$.
- Caspian Sea Region: The 90% detection level is at $m_b = 4.5$.
- Southern Iran Region: The 90% detection level is at $m_b = 4.3$.
- Greece-Turkey Region: The 90% detection level is at $m_b = 4.5$. The notch in the detection curve at $m_b = 4.8$ (indicated by an arrow) was not considered significant, since it was caused by an event which was reported by only three stations. Of these, only one reported a value of $m_b$. Therefore, the $m_b$ of this event was not considered to be reliable.
- Eastern Kazakh Test Area: The 90% detection level for presumed explosions from this area is just below $m_b = 5.5$. Even though the event population for this area is small, it was felt that this detection level estimate could be made, since all members of the population were presumed explosions and all were from one small area.

These results show that, insofar as the scope of the data base and the 90% detection level are concerned, only four general areas need be considered. These are the Kamchatka - Kurile Islands region, the Central Asia region including Southern Iran, the region encompassing Southeastern Europe and the Caspian Sea area, and the Eastern Kazakh test area.

In addition to the regional detection levels described above, histograms and their corresponding detection curves were constructed for winter (January through March) and summer (June through August) suites of events. These are presented in Figures VII-8 and VII-9. The 90% detection level for the winter suite lies at $m_b = 4.5$, while the 90% detection level for the summer suite lies at $m_b = 4.4$. This difference of 0.1 magnitude unit in the detection levels can be ascribed to the bursts of long-period non-propagating noise occuring during the winter months (Section III), which would tend to obscure events which would otherwise have been detected.

A comparison of the results yielded by this analysis with those reported for the preceeding year (Heiting, et al, 1972) shows that the 90% detection level is lower this year by 0.1 $m_b$ units for both the Central Asia and Kurile Islands - Kamchatka regions. This is probably due to the greater precision possible this year because of a larger data base, and to the exclusion this year of events from the Central Asia region which more properly belong in the Southeastern Europe or Caspian Sea regions.



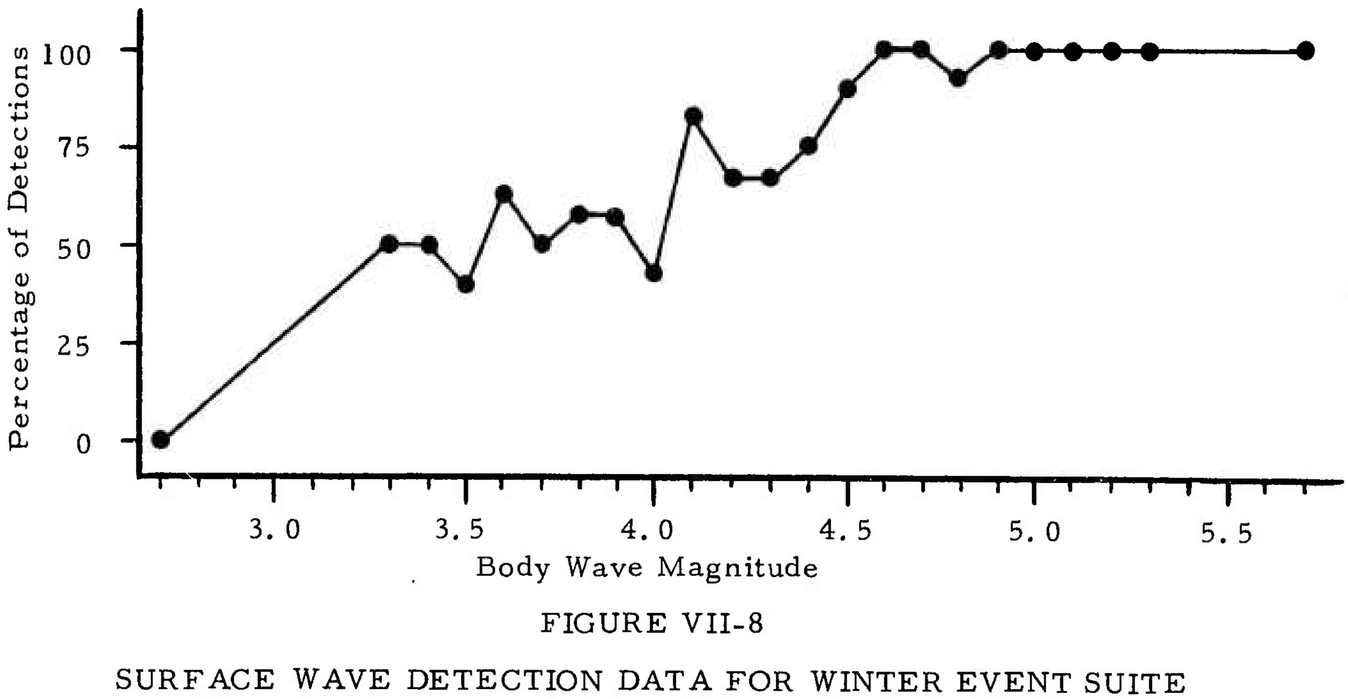




FIGURE VII-8

SURFACE WAVE DETECTION DATA FOR WINTER EVENT SUITE

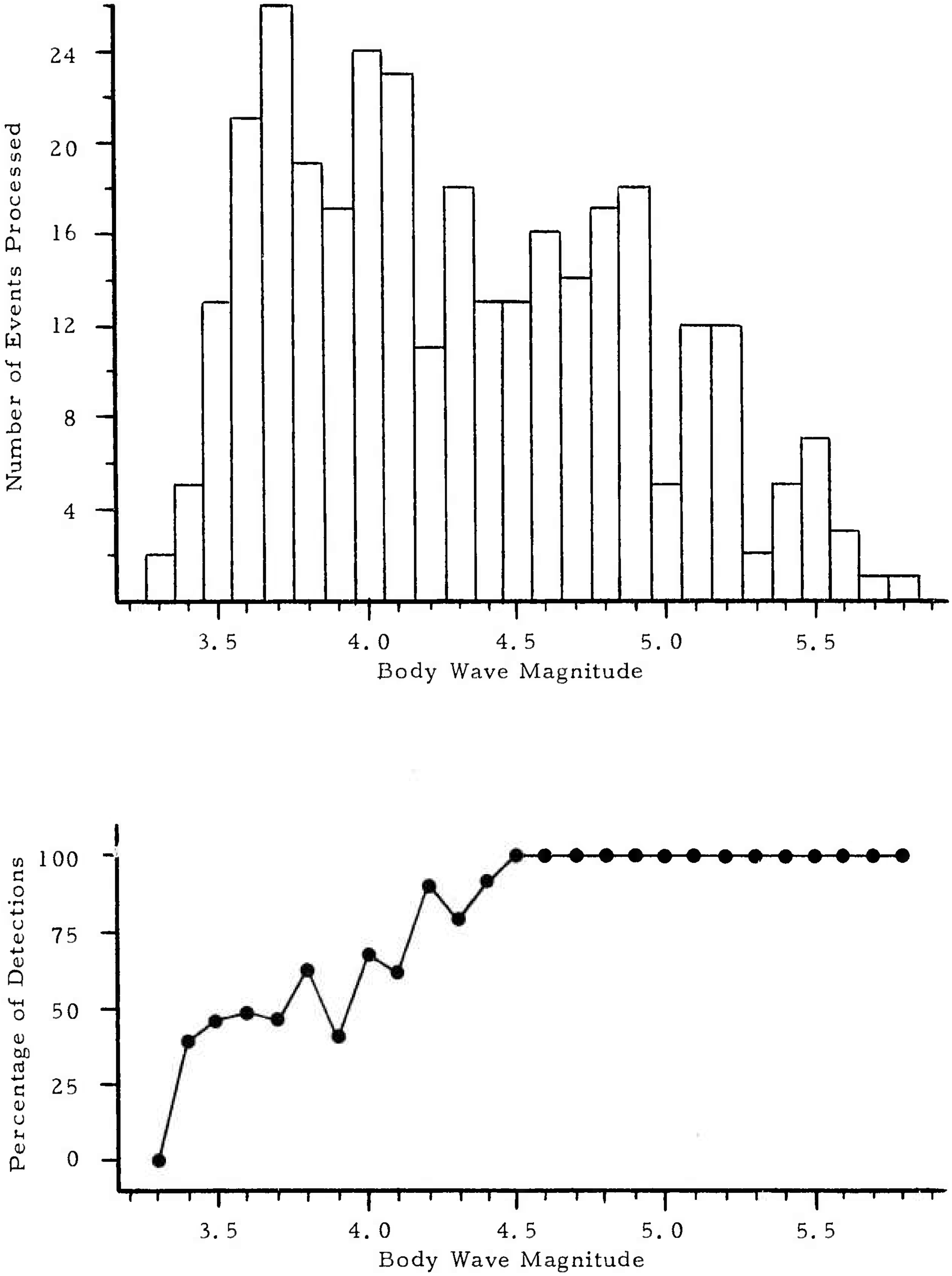



FIGURE VII-9

SURFACE WAVE DETECTION DATA FOR SUMMER EVENT SUITE

## SECTION VIII

## BEHAVIOR OF STANDARD DISCRIMINANTS

### A. MEASUREMENT OF $M_s$

Surface wave magnitudes ($M_s$) were computed for all of the events which were detected and listed in Appendix A. Whenever possible, values of $M_s$ were computed for all three components. For events which were not detected, an upper bound for the corresponding surface wave magnitude was computed from the largest peak-to-peak noise amplitude occurring within the signal gate. These upper bounds are designated by the symbol ) preceeding the $M_s$ value in Appendix A. The surface wave magnitude was determined for each event by the formula:

$$M_s = \log A/T + 1.66 \log \Delta$$

where:

- A is the largest peak-to-peak amplitude in millimicrons
- T is the period in seconds in the neighborhood of the peak
- $\Delta$ is the epicentral distance in degrees.

All measurements were made on beamsteered traces which had been bandpass filtered (0.025 - 0.055 Hz passband). The maximum peak amplitudes usually occurred near 25 second periods. However, for some of the more distant events, the maximum peak amplitudes were measured at periods between 28 and 32 seconds. To estimate the effect of the period at which the amplitude was measured on the resulting value of $M_s$, A/T values for 58 events were measured twice; once in the period range 20-25 seconds and once in the period range 26-32 seconds. The results indicated that the values of $M_s$ for Love waves were essentially the same for the two period ranges, while the values of $M_s$ for Rayleigh waves as measured in the period range 26-32 seconds may be as much as 0.1 $M_s$ units lower than those measured in the first period range. Since the accuracy of measurement only approaches 0.1 $M_s$ units, all $M_s$ values reported were measured on the largest amplitude present on the 0.025 to 0.055 Hz bandpass filtered trace without further concern for the period at which the amplitude was measured.

B. $M_s$ - $m_b$ AS A DISCRIMINANT

The $M_s$ - $m_b$ data for each region are presented in Figures VIII-1 through VIII-4. Only three regions had large enough event populations to allow comparison with the presumed explosion population. One other region, Taiwan, is presented; even though the event population is small, all of its events were detected. Each figure consists of two plots - one for $M_s$ measured on Love waves and one for $M_s$ measured on Rayleigh waves. In each plot, the corresponding data for presumed explosions are presented for purposes of comparison. On these plots, a circle represents an earthquake $M_s$ - $m_b$ data point, and a triangle represents a presumed explosion $M_s$ - $m_b$ data point. A vertical line below one of these symbols indicates an upper bound on $M_s$ for a non-detected event.

A least-mean-square-error fit was made for each data set. To avoid bias at lower values of $m_b$, where only those events having a relatively high $M_s$ were detected, the fit was made only on those values of $m_b$ which were at or above the 100 per cent detection level. Data points at values of $m_b$ greater than 5.5 were also excluded from the fit, since above this $m_b$ value the fit assumes a steeper slope (Tsai, 1972). These least-square fits are shown as solid lines over their intervals of definition. The dashed-line extension of these fits are presented as an aid in comparing the earthquake population fit with the presumed explosion fit. With the exception of the TWN

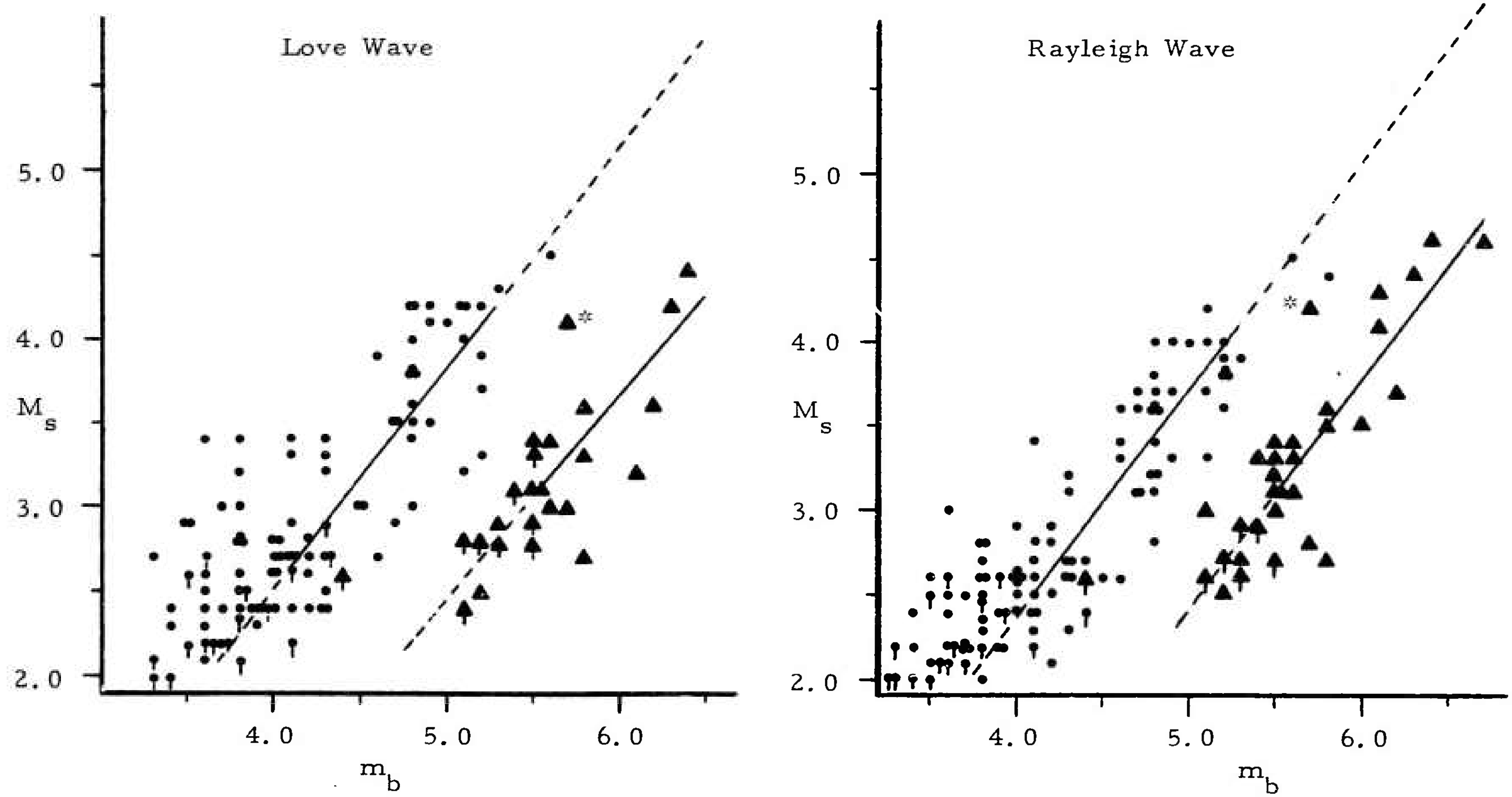



FIGURE VIII-1

$M_s$ VS. $m_b$ FOR KAMCHATKA REGION EVENTS

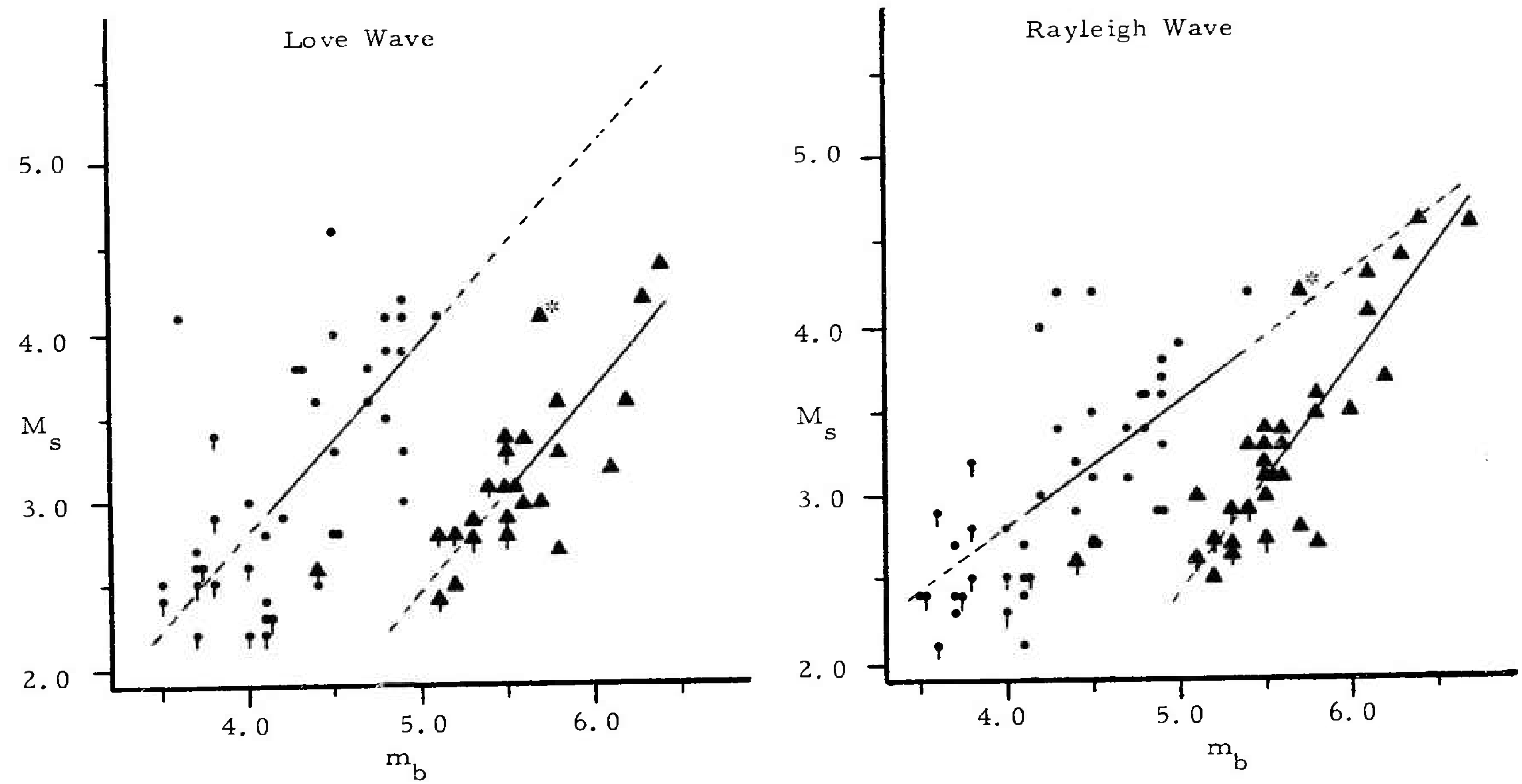



FIGURE VIII-2

$M_s$ VS. $m_b$ FOR KURILE ISLANDS REGION EVENTS

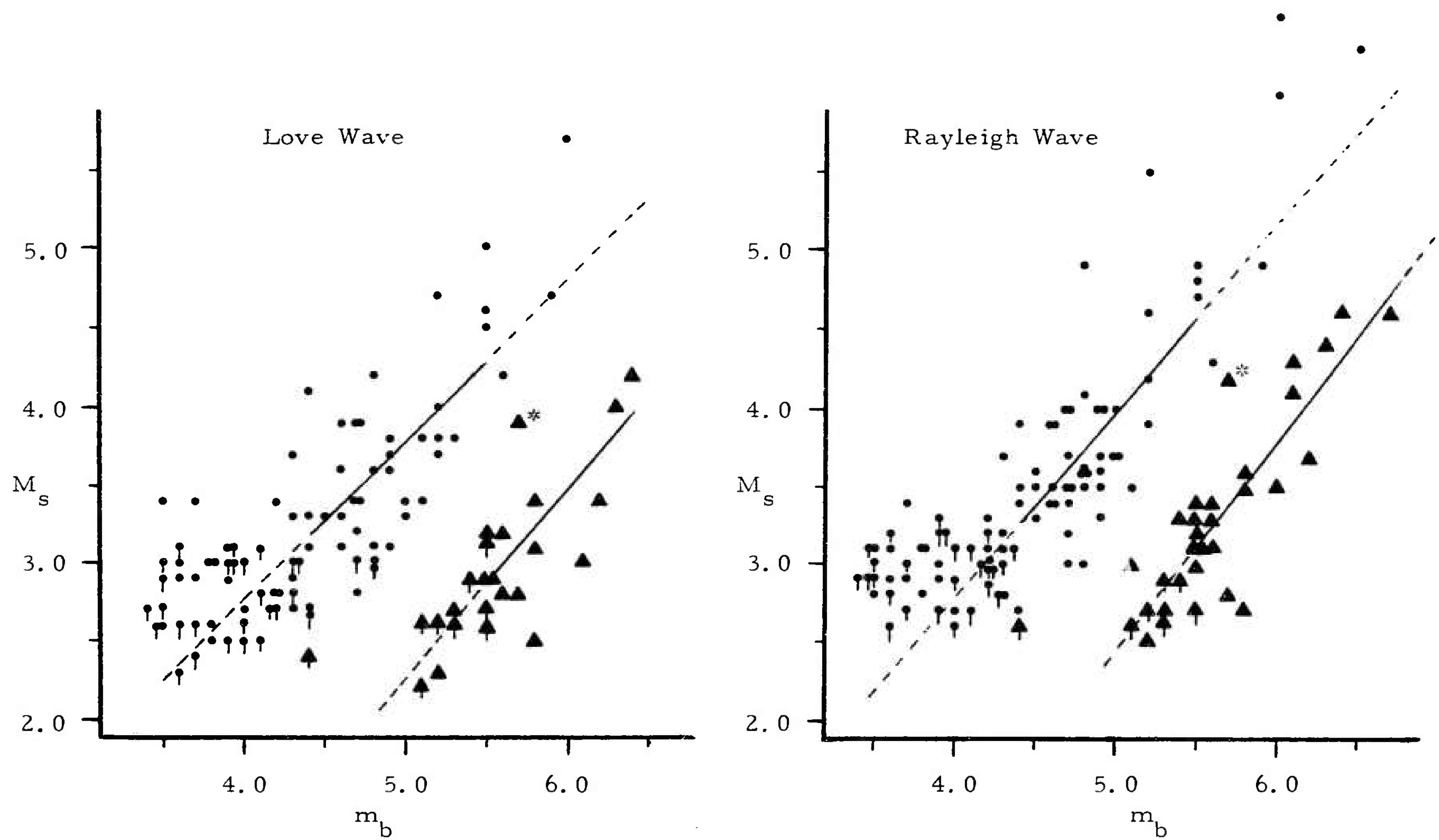



FIGURE VIII-3

$M_s$ VS. $m_b$ FOR CENTRAL ASIA REGION EVENTS

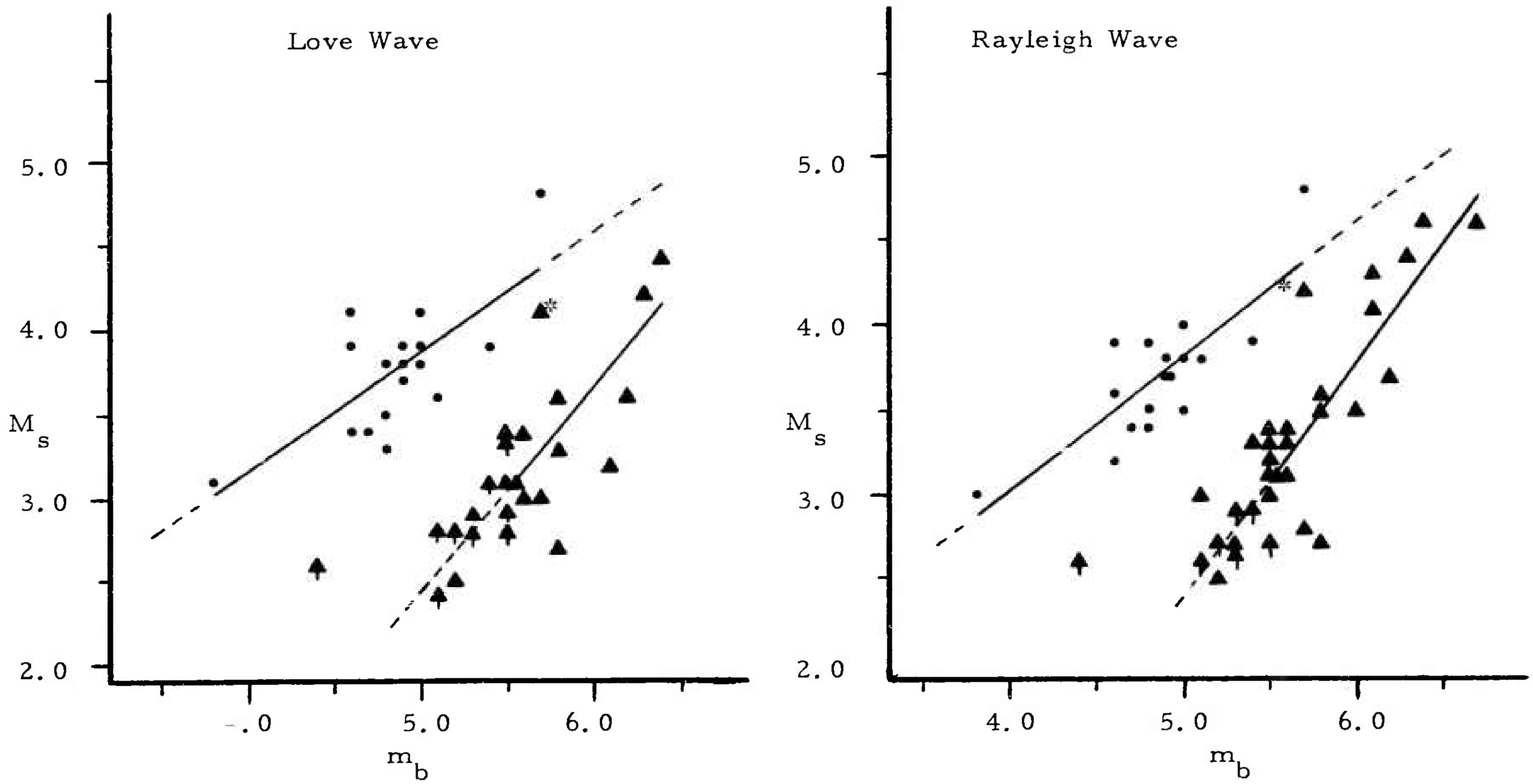



FIGURE VIII-4

$M_s$ VS. $m_b$ FOR TAIWAN REGION EVENTS region data and the KUR region LR-V data (which have slopes less than 1.0), the slopes of the earthquake populations are between 1.1 and 1.4 and are therefore parallel or near-parallel to the LQ-T and LR-V fits of the presumed explosion data.

In general, the plots show good separation between earthquake and presumed explosion populations. One presumed explosion, EKZ-345-04AL, has an abnormally high value of $M_s$ for both Love and Rayleigh waves. (This event is indicated by * on the plots.) However, the SDAC/LASA weekly summary reports this presumed explosion as a presumed double explosion with 8 second separation. If this is the case, the high $M_s$ values shown by this event can be explained by constructive interference of the two events. The poor separation shown by the Kurile Islands/Kamchatka events as reported last year (Heiting, el al, 1972) now appears to be due to the events from the southern Kurile Islands. The Kamchatka region events show complete separation from the presumed explosion population (with the exception of the presumed explosion EKZ-345-04AL, as described above). The Central Asia and Taiwan event populations also show complete separation from the presumed explosion population. Comparison of the least-mean-square-error fits indicates that, in every region, Love wave $M_s$ - $m_b$ is a better discriminant than Rayleigh wave $M_s$ - $m_b$.

Using only those earthquakes having $m_b$ values at or above the 100 per cent detection level and below 5.6, $M_s$ - $m_b$ relationships were computed for the entire body of data. By also computing the 95 per cent confidence limits for these relationships, it was possible to estimate the error involved in the computation. The resulting $M_s$ - $m_b$ relationships are:

for Love wave $M_s$ : $M_s = (1.2 \pm 0.2)m_b - (2.1 \pm 1.1)$ (163 events)

for Rayleigh wave $M_s$: $M_s = (1.2 \pm 0.2)m_b - (2.2 \pm 0.9)$ (205 events)

These relationships are clearly different than the Gutenberg-Richter relationship:

$$M_s = 1.59\ m_b - 3.97$$

and strongly suggest that the $M_s$ - $m_b$ slope in the region $5.6 \leq m_b \leq 4.2$ is significantly lower than that observed at higher magnitudes.

## C. AL AND AR AS DISCRIMINANTS

The parameter AR is related to the total Rayleigh wave energy in a seismic event. It was introduced by Brune, Espinosa, and Oliver (1963). It has been used by Evernden (1969), who also studied AL, the corresponding parameter for Love wave energy. The AR and AL parameters as used here were computed by summing the absolute values (in millimicrons) of the data points within the signal gate beginning at the expected arrival time of the signal and extending throughout the expected time of duration of the signal. The results were scaled as described earlier (Heiting, et al, 1972).

Only two regions, Kamchatka and Central Asia, contained enough data to make analysis of AL and AR meaningful. Figures VIII-5 and VIII-6 present these data. Open circles represent values of AL; solid circles represent values of AR. For comparison, presumed explosion values of AL and AR are plotted, using open and solid triangles respectively.

Examination of the data reveals that the parameters AL and AR have a fair discrimination capability. While there is some overlap of the earthquake and presumed explosion populations, the average separation is on the order of a factor of ten. The highest AL and AR values for a presumed explosion were measured on EKZ-345-04AL. If this event is removed from the presumed explosion data, for reasons stated earlier, the Central Asia AL and AR values will show no overlap with the presumed explosion values. The overlap of the Kamchatka-presumed explosion AR data will be greatly reduced and there will be no overlap for the corresponding AL data. In detail,

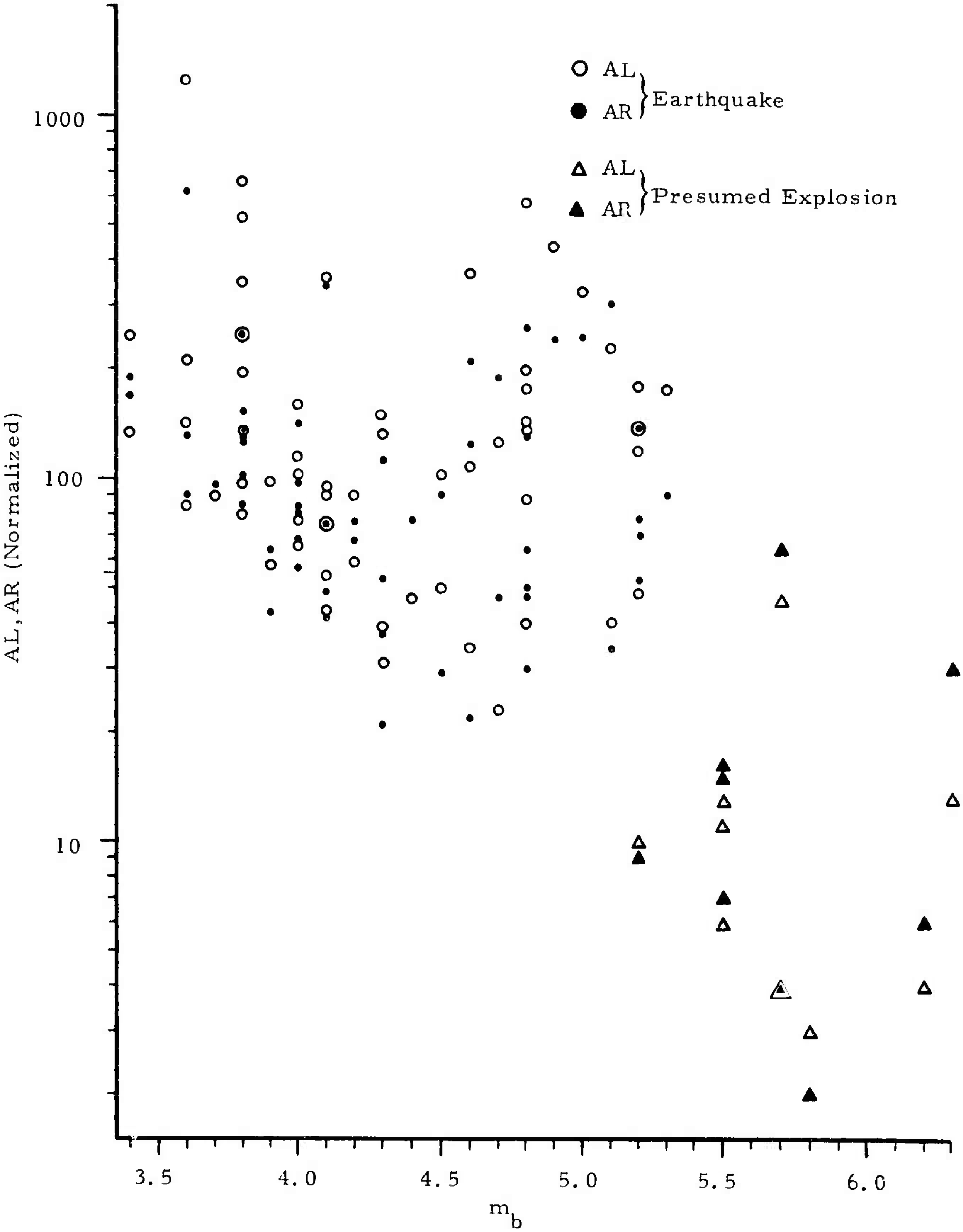



FIGURE VIII-5

AL AND AR VS. $m_b$ FOR KAMCHATKA REGION

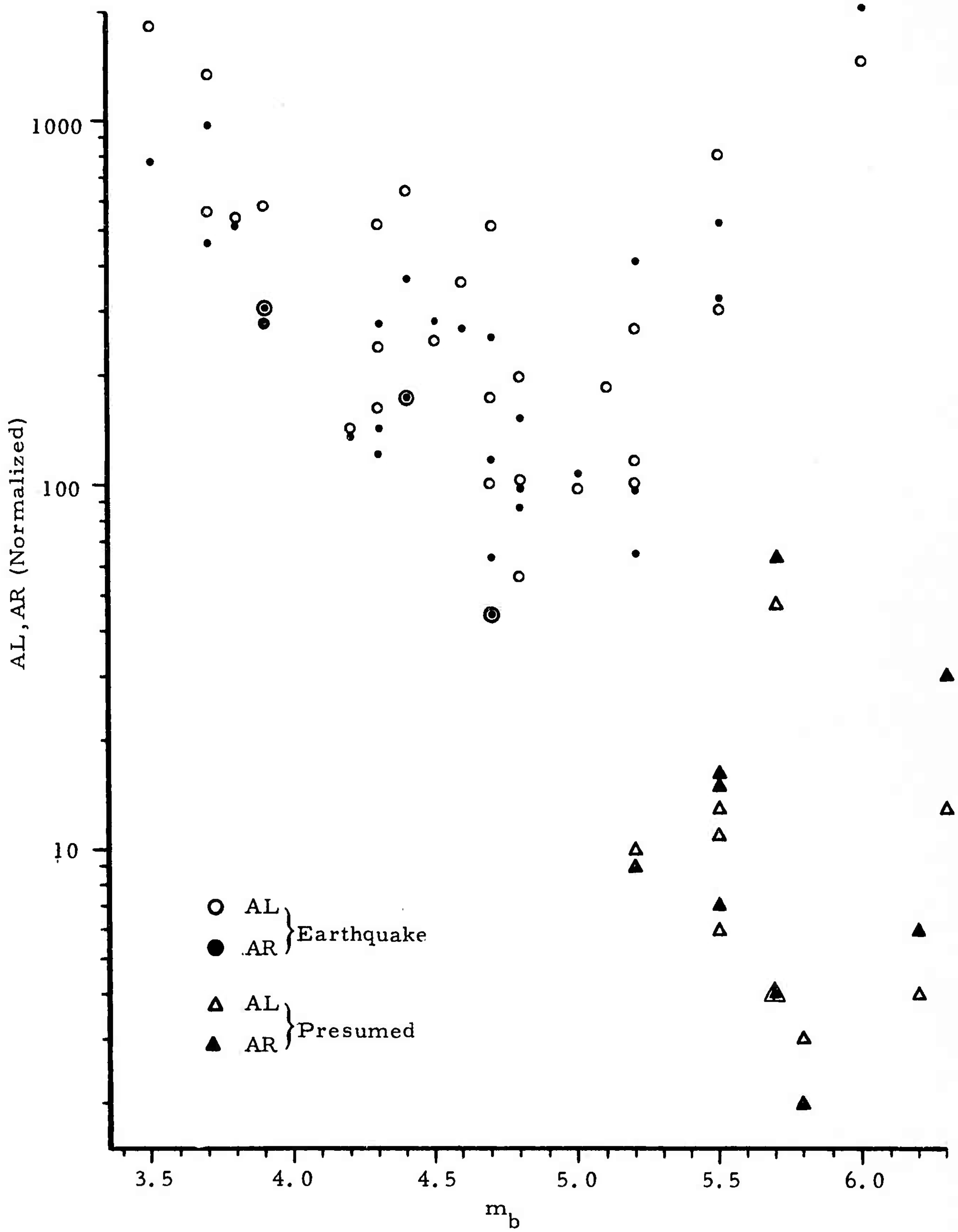



FIGURE VIII-6

AL AND AR VS. $m_b$ FOR CENTRAL ASIA REGION the separation between the lowest earthquake value and the highest presumed explosion value will be a factor of 1.8 for Kamchatka AL, 3.5 for Central Asia AL, and 1.5 for Central Asia AR. Therefore, AL appears to be a better discriminant than AR.

# SECTION IX
# CONCLUSIONS

## A. MAJOR RESULTS

Summarized below are the major results of each of the areas of evaluation:

1. Noise Analysis

- There appears to be a fairly constant background RMS noise level throughout the year at ALPA in the range of 7 - 10 $m\mu$.
- For the most part, the higher RMS noise levels (>14 $m\mu$) appear to be due to sudden increases in long-period non-propagating noise superimposed on the background noise level. Only a few of the high RMS noise levels may be due to storm-generated noise.
- The source azimuths of microseismic noise as recorded at ALPA rarely coincide with azimuths to the area of interest.

2. Matched Filter Studies

- There is considerable variation in SNNR improvement within a given region for both reference wavefo m and chirp matched filter
- The standard deviations are so large that mean SNNR improvement values are almost meaningless.

- Chirp matched filters appear to be slightly more effective than reference waveform matched filters.

- Although the use of matched filters does not appreciably affect the 90% detection thresholds, it increases the number of events detected and lowers the 50% detection thresholds.

3. S-Wave Processing Results

- The 90% S-wave detection threshold is just below $m_b$ = 4.5 for the Kamchatka - Kurile Island events.

- A higher percentage of summer events (30%) with $m_b$ below this 90% detection threshold was detected than of winter events (7%).

- For events with $m_b$ = 4.5 or greater, S-wave A/T values are a good discriminant.

4. ALPA Surface Wave Detection Capability

- By region, the 90% detection level (with a corresponding low (<1%) false alarm level) for surface waves occurs at:

| | |
|---|---|
| Kamchatka | $m_b$ = 4.1 |
| Kurile Islands | between $m_b$ = 4.1 and $m_b$ = 4.2 |
| Central Asia | between $m_b$ = 4.3 and $m_b$ = 4.4 |
| Caspian Sea | $m_b$ = 4.5 |
| Southern Iran | $m_b$ = 4.3 |
| Greece-Turkey | $m_b$ = 4.5 |
| Eastern Kazakh | $m_b$ = 5.5 (Presumed Explosions Only) |

- The 90% detection levels for the winter and summer event suites are at $m_b$ = 4.5 for the winter and at $m_b$ = 4.4 for the summer. This difference in detection levels is believed to be due to the slightly higher noise levels of the winter months.

5. Behavior of the Standard Discriminants

- As long as the peak-to-peak amplitude of a surface wave was measured at the highest amplitude, the resulting value of $M_s$ did not appear to depend upon the period of the waveform at which this amplitude was measured.

- With the exception of one presumed explosion, which may actually have been two explosions, the $M_s - m_b$ discrimination method achieved complete separation of earthquakes and presumed explosions. The Love wave $M_s - m_b$ appears to be a better discriminant than the Rayleigh wave $M_s - m_b$.

- Using all available earthquake data with $m_b$ values equal to or greater than the 100% detection level and less than 5.6, the following $M_s - m_b$ relationships were derived:

  for Love wave $M_s$: $M_s = (1.2 \pm 0.2)m_b - (2.1 \pm 1.1)$

  for Rayleigh wave $M_s$: $M_s = (1.2 \pm 0.2)m_b - (2.2 \pm 0.9)$

  The error estimates for the slope and intercept were measured from the 95% confidence limits of the computed least-mean-square-error fits to the data.

- AL and AR were not as successful in discrimination as $M_s - m_b$. With the removal from the data set of the presumed double explosion, separation between the earthquake and presumed explosion populations was complete except for the Kamchatka area AR data. AL data showed better separation than AR data.

## B. SUGGESTIONS FOR FUTURE ANALYSIS

The following areas should be investigated in any future analysis of ALPA.

- The indicated upward trend of the RMS noise level from day 241 to day 361 of 1972 should be investigated to more fully determine if it is different from the corresponding time period of 1971. This would require more noise samples taken in the above mentioned period and an extension of this period into 1973.

- More data for reference waveform matched filters and chirp matched filters should be compiled to make possible a more thorough investigation of their regional characteristics.

- More events from Central Asia should be processed to make possible the subdivision of this region. In particular, the differences in detection of Western Sinkiang events and Hindu Kush events should be investigated. At present, the small number of events in these areas makes it impossible to do more than note that most events from Western Sinkiang were detected, but few from the Hindu Kush area were detected.

## C. GENERAL CONCLUSIONS OF THE THREE-YEAR ALPA ARRAY EVALUATION

With the termination of the three-year evaluation of the detection and discrimination capabilities of ALPA, the following conclusions can be made about its characteristics and performance:

- Signal similarity across the array generally is good. As expected, similarity across the full 19-element array is less than that across the limited 9-element array. The average signal correlation coefficient for the vertical component is 0.84 for the full array and 0.93 for the limited array.

- The beamsteer signal attenuation averages about 2 dB across the full array and about 1 dB for the seven-element hexagonal subarray on all three components.

- The noise field at ALPA is characterized by a fairly constant background RMS noise level of 7 to 10 m$\mu$ (on a single channel) which is punctuated during the winter months by bursts of long-period non-propagating noise. These bursts can temporarily double or triple the RMS noise level and hence decrease detection capability. Propagating storm-generated noise is confined to a narrow band around 18 seconds and variations in this peak do not significantly affect detection capability. The source azimuths of propagating microseismic noise rarely coincide with azimuths to the area of interest. Noise levels are essentially the same on all three components.

- Noise reduction achieved by beamsteering is very close to $\sqrt{N}$, hence output beam RMS noise levels usually are between 1.5 and 2.5 m$\mu$.

- The ALPA noise is not time stationary; substantial variations in wave number structure have been observed at the micro-seismic peak in a two-hour period. Unless the design noise is within a very few hours of the data to which a multichannel filter is to be applied, there is no advantage of a multichannel filter over beamsteering.

- The matched filter studies indicate that, in general, chirp matched filters perform slightly better than reference waveform matched filters in that they yield essentially the same mean

SNNR improvements as the reference waveforms but have less variation in improvement among test events. Since matched filters decreased the number of otherwise undetected events by about 20%, thereby lowering the 50% detection levels, they are of value in event detection studies.

- Two-component beamforming as performed in 1971 yielded SNNR gains over the one component beam of only one to two dB in the bandpassed output beam. Therefore, two-component beamforming was considered unsatisfactory as a signal enhancement technique and was not used in the 1972 evaluation.

- The S-wave 90% detection threshold was determined to be at $m_b = 4.5$ for Kurile Islands - Kamchatka events and at $m_b = 5.5$ for Central Asian events. The S-wave A/T discriminant is good for events having $m_b$ values at or above these detection thresholds.

- The surface wave 90% detection levels were determined to be at $m_b = 4.1$ for Kurile Islands - Kamchatka events, at $m_b = 4.4 \pm 0.1$ for Eurasian events, and at $m_b = 5.5$ for Eastern Kazakh presumed explosions. The winter suite 90% detection level was found to be at $m_b = 4.5$ and the summer 90% detection level at $m_b = 4.4$. This difference is believed to be due to the higher RMS noise levels occurring during the winter months. Detection levels for a nine-element subarray are only 0.1 to 0.2 magnitude units above those for the full array.

- The best earthquake-presumed explosion discriminant appears to be the $M_s$ - $m_b$ relationship. The $M_s$ - $m_b$ relationship determined from Love wave energy is a slightly better discriminant than the corresponding relationship determined from Rayleigh wave energy. The AL-$m_b$ and AR-$m_b$ discriminants, while inferior to the $M_s$-$m_b$ discriminants, are useful in earthquake presumed explosion discrimination studies. AL-$m_b$ is a better discriminant than AR-$m_b$.

- Using only those earthquakes having $m_b$ values at or above the 100% detection level and below $m_b$ = 5.6, the following $M_s$-$m_b$ relationships were determined:

for Love wave $M_s$: $M_s = (1.2 \pm 0.2)m_b - (2.1 \pm 1.1)$

for Rayleigh wave $M_s$: $M_s = (1.2 \pm 0.2)m_b - (2.2 \pm 0.9)$

The error estimates for the slope and intercept were determined from the 95% confidence limits. These relationships are clearly different than the Gutenberg-Richter relationship $M_s = 1.59\ m_b - 3.97$ and indicate that the $M_s$ - $m_b$ slope in the $4.2 \leq m_b \leq 5.6$ range is lower than that at higher magnitudes.

## SECTION X
## REFERENCES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# APPENDIXES

# APPENDIX A

## THE COMBINED 1970 - 1972 DATA BASE

All events used in this evaluation of ALPA are listed on the following pages. The events are listed in chronological order starting on May 17, 1970 and ending on December 10, 1972. The parameters listed are: event name, month of occurrence (Mo.), day of occurrence (Day), origin time, latitude (Lat/$^{\circ}$N), longitude (Long/$^{\circ}$E), body wave magnitude ($m_b$), Rayleigh surface wave magnitude ($(M_s)_R$), Love surface wave magnitude ($(M_s)_L$), region as defined in Section IV (Reg), depth (D), detection (Det.), number of sites used in processing (NS), and information source (IS).

The symbols accompanying some of these parameters are as follows:

| | |
|---|---|
| * | preceeding $m_b$ value - $m_b$ has been recalculated using teleseismic data only. |
| ) | preceeding $M_s$ value - upper bound of $M_s$ for a non-detected event. |
| M | preceeding $M_s$ value - detection by reference waveform matched filter. |
| C | preceeding $M_s$ value - detection by chirp matched filter. |
| X | preceeding information source - presumed explosion |
| -- | in any column - no information available. |

The information source code is:

P - parameters taken from Preliminary Determination of Epicenters Monthly Summary

I - parameters taken from International Seismological Month verified event list

J - parameters taken from International Seismological Month unverified event list

L - parameters taken from SDAC/LASA Weekly Summary

N - parameters taken from NORSAR Seismic Event Summary.

COMPLETE LIST OF EVENTS USED IN ALPA EVALUATION
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| Event Name | Mo | Day | Origin Time | Lat °N | Long °E | $m_b$ | $(M_s)_R$ | $(M_s)_L$ | Reg | D | Det | NS | IS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CAU/137/06AL | 5 | 17 | 6.49. 6 | 43.0 | 46.9 | 5.0 | 4.7 | -- | CSP | N | D | -- | P |
| GEO/138/05AL | 5 | 18 | 5.36.44 | 42.6 | 46.6 | 4.5 | 3.3 | -- | CSP | N | D | -- | P |
| MON/139/08AL | 5 | 19 | 8.11. 9 | 47.0 | 95.8 | 4.3 | 2.9 | -- | --- | N | D | -- | P |
| MON/143/14AL | 5 | 23 | 14.51.35 | 50.1 | 91.6 | 4.5 | 3.6 | -- | --- | 43 | D | -- | P |
| KUR/144/00AL | 5 | 24 | 0.41.20 | 43.8 | 147.6 | 4.5 | 3.5 | 4.0 | KUR | N | D | -- | P |
| KUR/144/09AL | 5 | 24 | 9.18.16 | 43.6 | 147.7 | 4.5 | 3.1 | 3.3 | KUR | 45 | D | -- | P |
| KAM/144/16AL | 5 | 24 | 16.33.18 | 55.0 | 162.7 | 4.7 | 3.7 | -- | KAM | N | D | -- | P |
| CEN/151/03BS | 5 | 31 | 3.31.54 | 37.4 | 73.3 | 4.1 | )2.8 | -- | CA | N | ND | -- | P |
| GEO/151/10AL | 5 | 31 | 10.25.50 | 43.0 | 47.0 | 4.6 | 3.5 | -- | CSP | 25 | D | -- | P |
| KUR/153/23AL | 6 | 2 | 23.33.30 | 45.7 | 150.9 | 5.4 | 4.2 | -- | KUR | 20 | D | -- | P |
| ALM/156/04OE | 6 | 5 | 4.53. 6 | 42.5 | 78.8 | 6.0 | 6.5 | -- | CA | 20 | D | -- | P |
| SIB/156/10AL | 6 | 5 | 10.31.54 | 63.4 | 146.2 | 5.5 | 4.6 | -- | --- | N | D | -- | P |
| KUR/163/03AL | 6 | 12 | 3. 5.21 | 44.9 | 148.9 | 4.9 | 3.8 | -- | KUR | N | D | -- | P |
| CEN/163/16AL | 6 | 12 | 16. 0. 1 | 40.7 | 78.4 | 5.0 | 3.7 | -- | CA | N | D | -- | P |
| CHI/168/11AL | 6 | 17 | 11.50. 7 | 24.2 | 102.4 | 4.6 | 4.4 | -- | --- | N | D | -- | P |
| KAM/170/18AL | 6 | 19 | 18.52.34 | 57.3 | 163.3 | 5.2 | 3.9 | -- | KAM | N | D | -- | P |
| MON/171/08AL | 6 | 20 | 8.32.17 | 45.5 | 98.4 | 4.1 | 3.7 | -- | --- | N | D | -- | P |
| HON/173/04AL | 6 | 22 | 4.13.59 | 38.7 | 141.1 | 4.1 | 2.6 | -- | --- | 14 | D | -- | P |
| CHI/175/00AL | 6 | 24 | 0.43. 2 | 28.9 | 95.6 | 4.8 | 4.1 | -- | CA | N | D | -- | P |
| KUR/178/03AL | 6 | 27 | 3.24.52 | 48.4 | 155.6 | 4.8 | 3.8 | -- | KAM | N | D | -- | P |
| IRA/178/07AL | 6 | 27 | 7.57.53 | 35.2 | 50.7 | 4.9 | 3.9 | -- | CSP | 14 | D | -- | P |
| WRS/178/09AL | 6 | 27 | 8. 4.29 | 42.3 | 53.6 | 4.9 | 4.0 | -- | CSP | N | D | -- | P |
| ALB/178/18AL | 6 | 27 | 18.57.12 | 41.5 | 19.4 | 4.5 | 3.4 | -- | GT | 25 | D | -- | P |
| KAM/179/11AL | 6 | 28 | 11. 1.54 | 53.4 | 160.4 | 5.8 | 4.4 | -- | KAM | 23 | D | -- | P |
| GRC/184/00AL | 7 | 3 | 0.41. 1 | 38.7 | 20.4 | 5.1 | 3.9 | -- | GT | N | D | -- | P |
| CHI/188/04AL | 7 | 7 | 3.55.42 | 38.1 | 95.4 | 4.3 | )3.0 | -- | CA | N | ND | -- | P |
| GRC/194/00AL | 7 | 13 | 0.46.47 | 38.9 | 20.6 | 4.7 | 3.7 | -- | GT | N | D | -- | P |
| HON/201/03AL | 7 | 20 | 3. 2.20 | 29.8 | 142.2 | 4.4 | 2.9 | -- | --- | 40 | D | -- | P |

## COMPLETE LIST OF EVENTS USED IN ALPA EVALUATION
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| Event Name | Mo | Day | Origin Time | Lat °N | Long °E | $m_b$ | $(M_s)_R$ | $(M_s)_L$ | Reg | D | Det | NS | IS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| FKZ/202/03AL | 7 | 21 | 3. 2.57 | 50.0 | 77.8 | 5.4 | 3.3 | -- | FKZ | 00 | D | -- | XP |
| EKZ/205/03AL | 7 | 24 | 3.56.57 | 49.8 | 78.2 | 5.3 | 2.7 | -- | FKZ | 00 | D | -- | XP |
| KYU/206/22AL | 7 | 25 | 22.41.11 | 32.2 | 131.7 | 6.1 | 6.5 | -- | --- | 34 | D | -- | P |
| KYU/207/07AL | 7 | 26 | 7.10.36 | 32.2 | 131.8 | 6.1 | 5.8 | -- | --- | 35 | D | -- | P |
| CHI/210/05AL | 7 | 29 | 5.50.56 | 39.9 | 77.8 | 5.2 | 5.5 | -- | CA | 13 | D | -- | P |
| BUR/210/10AL | 7 | 29 | 10.16.19 | 26.0 | 95.4 | 6.5 | 6.3 | -- | CA | 59 | D | -- | P |
| IRA/211/00AL | 7 | 30 | 0.52.20 | 37.8 | 55.9 | 5.7 | 5.8 | -- | CSP | 19 | D | -- | P |
| KUR/212/01AL | 7 | 31 | 1.53.17 | 43.4 | 147.5 | 4.9 | 3.7 | 4.2 | KUR | 49 | D | -- | P |
| CHI/212/13AL | 7 | 31 | 13.10.47 | 28.6 | 103.6 | 5.5 | 4.5 | -- | --- | 25 | D | -- | P |
| JAP/217/20AL | 8 | 5 | 20.10.13 | 33.6 | 134.6 | 4.0 | 3.2 | -- | --- | 13 | D | -- | P |
| HON/218/02AL | 8 | 6 | 2.37.49 | 31.7 | 139.4 | 4.7 | 3.5 | -- | --- | 29 | D | -- | P |
| CHI/218/05AL | 8 | 6 | 5.44.14 | 40.4 | 78.8 | 4.5 | 3.3 | -- | CA | N | D | -- | P |
| KUR/219/01AL | 8 | 7 | 1.43.19 | 43.8 | 148.3 | 5.0 | 3.9 | -- | KUR | N | D | -- | P |
| KUR/219/13AL | 8 | 7 | 13.40.22 | 43.6 | 148.4 | 4.5 | 3.7 | -- | KUR | N | D | -- | P |
| CHI/220/11AL | 8 | 8 | 11.46.31 | 44.3 | 81.2 | 4.7 | 4.0 | -- | CA | N | D | -- | P |
| KUR/220/14AL | 8 | 8 | 14.27.51 | 44.6 | 143.5 | 4.4 | 2.9 | -- | KUR | N | D | -- | P |
| HON/221/15AL | 8 | 9 | 15.18.40 | 40.1 | 143.7 | 4.2 | 2.9 | 3.1 | --- | N | D | -- | P |
| SIN/221/16AL | 8 | 9 | 16.12.17 | 40.0 | 77.8 | 4.5 | 3.5 | -- | CA | N | D | -- | P |
| TIB/223/01AL | 8 | 11 | 1. 6.19 | 34.1 | 79.3 | 4.8 | 3.6 | -- | CA | N | D | -- | P |
| BUR/225/07AL | 8 | 13 | 7. 0.42 | 24.7 | 93.9 | 4.7 | 3.7 | 4.1 | CA | 40 | D | -- | P |
| KAM/225/22AL | 8 | 13 | 22.44.52 | 53.7 | 160.4 | 4.6 | 3.3 | -- | KAM | N | D | -- | P |
| ALB/231/02AL | 8 | 19 | 2. 1.53 | 41.1 | 19.8 | 5.2 | 5.1 | -- | GT | N | D | -- | P |
| KAM/231/09AL | 8 | 19 | 9.57.40 | 52.9 | 159.4 | 4.7 | 3.1 | 3.5 | KAM | 55 | D | -- | P |
| IRA/232/15AL | 8 | 20 | 15.29.52 | 29.3 | 51.6 | 4.4 | 3.6 | -- | SIR | 33 | D | -- | P |
| KAM/234/11AL | 8 | 22 | 11.27.15 | 53.6 | 161.3 | 5.1 | 3.7 | 4.2 | KAM | N | D | -- | P |
| GRC/234/12AL | 8 | 22 | 12. 4.48 | 38.1 | 20.0 | 4.6 | 3.2 | -- | GT | N | D | -- | P |
| HON/238/02OC | 8 | 26 | 2.18.58 | 29.2 | 142.3 | 4.3 | 3.2 | -- | --- | N | D | -- | P |
| ALB/241/10AL | 8 | 29 | 10.42.18 | 41.5 | 19.4 | 4.4 | 3.3 | -- | GT | 38 | D | -- | P |

## COMPLETE LIST OF EVENTS USED IN ALPA EVALUATION
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| Event Name | Mo | Day | Origin Time | Lat °N | Long °E | $m_b$ | $(M_s)_R$ | $(M_s)_L$ | Reg | D | Det | NS | IS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ERS/241/14AL | 8 | 29 | 14.59.23 | 51.1 | 135.3 | 5.4 | 4.0 | -- | --- | N | D | -- | P |
| KAM/242/00AL | 8 | 30 | 0.38.40 | 52.1 | 159.6 | 5.2 | 4.8 | -- | KAM | N | D | -- | P |
| KAM/242/03AL | 8 | 30 | 3.13.59 | 52.2 | 159.7 | 4.8 | 3.6 | 3.8 | KAM | N | D | -- | P |
| KAM/242/07AL | 8 | 30 | 7. 3.28 | 52.9 | 159.1 | 3.8 | 2.6 | 3.0 | KAM | N | D | -- | P |
| IRA/242/16AL | 8 | 30 | 16.17.31 | 37.4 | 56.0 | 5.1 | 4.1 | -- | CSP | N | D | -- | P |
| CAU/243/04AL | 8 | 31 | 4.12.36 | 41.1 | 44.0 | 4.0 | 3.0 | -- | CSP | N | D | -- | P |
| EKZ/249/04AL | 9 | 6 | 4. 2.57 | 49.8 | 78.1 | 5.6 | 3.3 | -- | EKZ | 00 | D | -- | XP |
| KUR/257/19AL | 9 | 14 | 19.44.32 | 43.5 | 147.9 | 5.1 | 2.7 | 4.1 | KUR | 30 | D | -- | P |
| CRS/287/05AL | 10 | 14 | 5.59.57 | 73.3 | 55.1 | 6.7 | 4.6 | -- | --- | 00 | D | -- | XP |
| EKZ/346/07AL | 12 | 12 | 7. 0.57 | 43.9 | 54.8 | 6.1 | 4.1 | -- | --- | 00 | D | -- | XP |
| EKZ/351/07AL | 12 | 17 | 7. 0.57 | 49.7 | 78.1 | 5.5 | 3.3 | -- | EKZ | 00 | D | -- | XP |
| WKZ/357/07AL | 12 | 23 | 7. 0.57 | 43.8 | 54.8 | 6.1 | 4.3 | -- | --- | 00 | D | -- | XP |
| EKZ*081*04AL | 3 | 22 | 4.32.58 | 49.7 | 78.2 | 5.8 | 3.6 | 3.6 | EKZ | 00 | D | 4 | XP |
| URL*082*06AL | 3 | 23 | 6.59.56 | 61.3 | 56.5 | 5.6 | 3.4 | 3.4 | --- | 00 | D | 5 | XP |
| CHI*156*10AL | 6 | 5 | 10.21.28 | 37.3 | 113.7 | 4.7 | 3.9 | 4.3 | --- | 33 | D | 11 | P |
| EKZ*157*04QC | 6 | 6 | 4. 2.57 | 50.0 | 77.6 | 5.5 | 3.2 | )2.9 | EKZ | 00 | D | 4 | XP |
| CHI*161*19AL | 6 | 10 | 19.28.15 | 40.0 | 116.0 | 4.0 | 3.2 | 3.5 | --- | -- | D | 11 | L |
| KAM*162*04AL | 6 | 11 | 4.24. 3 | 51.4 | 159.3 | 4.8 | 3.7 | 4.0 | KAM | 33 | D | 4 | P |
| KAM*163*07AL | 6 | 12 | 7.25. 0 | 52.0 | 159.0 | 3.5 | 2.6 | 2.9 | KAM | -- | D | 6 | L |
| SIN*166*07AL | 6 | 15 | 7.39.37 | 39.0 | 80.0 | 5.9 | 4.9 | 4.9 | CA | 33 | D | 10 | P |
| KAM*166*14AL | 6 | 15 | 14. 4. 9 | 52.8 | 160.8 | 5.1 | 4.2 | 4.2 | KAM | 55 | D | 10 | P |
| SIN*166*23AL | 6 | 15 | 23. 7. 1 | 41.0 | 80.0 | 4.6 | 3.5 | -- | CA | -- | D | 5 | L |
| SIN*166*23AL | 6 | 15 | 23.17.34 | 41.6 | 79.2 | 4.9 | 3.5 | -- | CA | 33 | D | 5 | P |
| MON*167*03AL | 6 | 16 | 3.16.30 | 49.0 | 92.0 | 3.9 | 3.2 | 3.1 | --- | -- | D | 5 | L |
| KUR*167*09AL | 6 | 16 | 9. 5.29 | 48.0 | 154.0 | 4.1 | 2.7 | 2.8 | KUR | -- | D | 4 | L |
| SIN*167*13AL | 6 | 16 | 13.46.51 | 41.3 | 79.3 | 5.1 | 3.5 | 3.6 | CA | 33 | D | 4 | P |
| KAM*168*08AL | 6 | 17 | 8.20.47 | 54.0 | 161.0 | 4.1 | 2.8 | 2.9 | KAM | -- | D | 7 | L |
| KUR*168*09AL | 6 | 17 | 9.32. 5 | 44.4 | 148.9 | 4.9 | 2.9 | 3.3 | KUR | 33 | D | 7 | P |

## COMPLETE LIST OF EVENTS USED IN ALPA EVALUATION
## (PAGE 4 OF 20)

| Event Name | Mo | Day | Origin Time | Lat °N | Long °E | $m_b$ | $(M_s)_R$ | $(M_s)_L$ | Reg | D | Det | NS | IS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SIN*168*15AL | 6 | 17 | 15.20.12 | 41.3 | 79.4 | 4.9 | 3.3 | 3.3 | CA | 33 | D | 9 | P |
| FKZ*170*04OC | 6 | 19 | 4. 3.58 | 50.0 | 77.7 | 5.5 | 3.0 | )3.4 | FKZ | 00 | D | 6 | XP |
| SIN*170*17AL | 6 | 19 | 17.23. 3 | 41.5 | 79.3 | 5.2 | 4.6 | 4.9 | CA | 33 | D | 10 | P |
| SIN*170*21AL | 6 | 19 | 21. 8.46 | 41.5 | 79.4 | 4.7 | 3.4 | 3.4 | CA | 33 | D | 4 | P |
| HOK*177*08AL | 6 | 26 | 8.56.24 | 40.0 | 142.0 | 4.9 | 3.5 | 3.4 | --- | 49 | D | 10 | P |
| CAU*179*19AL | 6 | 28 | 19.53.46 | 42.0 | 43.0 | 4.6 | 3.3 | 3.2 | CSP | 34 | D | 13 | P |
| KUR*180*15AL | 6 | 29 | 15.11.33 | 45.3 | 151.7 | 4.8 | 3.6 | 3.5 | KUR | 50 | D | 12 | P |
| KUR*181*09AL | 6 | 30 | 9.31.20 | 50.0 | 158.0 | 3.8 | )2.5 | 2.8 | KAM | -- | D | 9 | L |
| SIN*181*13AL | 6 | 30 | 13.36. 0 | 39.0 | 79.0 | 4.6 | 3.4 | 3.3 | CA | -- | D | 12 | L |
| SAK*182*14AL | 7 | 1 | 14. 3.27 | 47.0 | 143.0 | 4.9 | )2.4 | 2.9 | --- | 33 | D | 10 | L |
| HIN*182*14AL | 7 | 1 | 14.37.26 | 36.7 | 69.3 | 4.6 | 3.4 | 3.5 | CA | 33 | D | 12 | P |
| KUR*182*21AL | 7 | 1 | 21.57.32 | 44.0 | 148.0 | 3.9 | -- | -- | KUR | 33 | ND | 11 | L |
| SIN*184*04AL | 7 | 3 | 4.26.22 | 41.3 | 79.3 | 4.9 | 3.6 | 3.8 | CA | 17 | D | 14 | P |
| WRS*184*17OC | 7 | 3 | 17.30.17 | 54.0 | 44.0 | 3.9 | -- | -- | --- | 33 | ND | 10 | L |
| KUR*185*15OD | 7 | 4 | 15.29.22 | 43.7 | 147.5 | 4.4 | 3.2 | 3.6 | KUR | 33 | D | 8 | P |
| HOK*185*19OC | 7 | 4 | 19.23.54 | 41.0 | 147.0 | 3.5 | )2.6 | 2.8 | --- | 33 | D | 11 | L |
| WRS*190*14AL | 7 | 9 | 14.51. 8 | 61.0 | 37.0 | 3.8 | -- | -- | --- | 33 | ND | 12 | L |
| KUR*190*16AL | 7 | 9 | 16.44.16 | 43.5 | 147.7 | 4.5 | 4.2 | 4.6 | KUR | 46 | D | 8 | P |
| KUR*191*02AL | 7 | 10 | 2. 4.28 | 51.0 | 153.0 | 3.6 | -- | -- | KUR | 33 | ND | 12 | L |
| KUR*191*03AL | 7 | 10 | 3. 5. 1 | 43.6 | 147.7 | 4.8 | 3.6 | 4.1 | KUR | 36 | D | 12 | P |
| KUR*191*14AL | 7 | 10 | 14.29. 2 | 44.0 | 149.0 | 4.3 | 3.4 | 3.8 | KUR | 33 | D | 12 | L |
| URL*191*16OC | 7 | 10 | 16.59.59 | 62.4 | 55.2 | 5.3 | )2.9 | )2.9 | --- | 00 | ND | 10 | XP |
| FKZ*192*05AL | 7 | 11 | 5.10.37 | 52.0 | 76.0 | 3.7 | )2.8 | -- | --- | 33 | ND | 12 | L |
| KAM*193*02AL | 7 | 12 | 2.12.30 | 53.1 | 160.0 | 4.9 | 3.3 | 3.5 | KAM | 33 | D | 10 | P |
| KUR*199*12OC | 7 | 18 | 12.32.38 | 51.0 | 157.0 | 4.3 | 2.3 | 2.5 | KAM | 33 | D | 13 | L |
| SWR*200*20AL | 7 | 19 | 20.41.20 | 49.0 | 39.0 | 3.8 | 3.2 | )3.0 | --- | 33 | D | 13 | L |
| KAM*201*05AL | 7 | 20 | 5.33.24 | 56.0 | 161.0 | 3.7 | -- | -- | KAM | 33 | ND | 15 | L |
| BAL*201*15AL | 7 | 20 | 15.25.34 | 52.0 | 118.0 | 4.0 | 2.9 | 2.8 | --- | 33 | D | 15 | L |

COMPLETE LIST OF EVENTS USED IN ALPA EVALUATION
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| Event Name | Mo | Day | Origin Time | Lat °N | Long °E | $m_b$ | $(M_s)_R$ | $(M_s)_L$ | Reg | D | Det | NS | IS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WRS*202*15TD | 7 | 21 | 15.49.27 | 52.0 | 54.0 | 3.8 | -- | -- | --- | 33 | ND | 5 | L |
| KUR*202*23AL | 7 | 21 | 23.50.14 | 47.0 | 147.0 | 3.8 | -- | -- | --- | 33 | ND | 14 | L |
| HOK*203*16AL | 7 | 22 | 16. 4.16 | 41.0 | 147.0 | 3.6 | -- | -- | --- | 33 | ND | 8 | L |
| KUR*203*22OC | 7 | 22 | 22.56. 5 | 44.0 | 149.0 | 4.3 | 4.2 | 3.8 | KUR | 33 | D | 14 | L |
| KAM*204*08AL | 7 | 23 | 8. 1.23 | 52.7 | 160.7 | 4.8 | 3.6 | 4.2 | KAM | 33 | D | 17 | P |
| KUR*204*12AL | 7 | 23 | 12.45.12 | 46.0 | 150.0 | 3.7 | -- | -- | KUR | 33 | ND | 14 | L |
| KUR*205*04AL | 7 | 24 | 4.19.41 | 45.0 | 147.0 | 3.6 | -- | -- | KUR | 33 | ND | 13 | L |
| SWR*205*11AL | 7 | 24 | 11.11.42 | 48.0 | 28.0 | 3.5 | -- | -- | --- | 33 | ND | 13 | L |
| TAD*205*11AL | 7 | 24 | 11.43.39 | 39.5 | 73.2 | 5.6 | 4.3 | 4.4 | CA | 33 | D | 15 | P |
| KUR*206*00AL | 7 | 25 | 0.41.26 | 50.0 | 154.0 | 4.1 | 2.5 | 2.5 | --- | 33 | D | 13 | L |
| KAM*206*01AL | 7 | 25 | 1.23.19 | 55.0 | 163.0 | 4.0 | -- | -- | KAM | 33 | ND | 14 | L |
| KAM*206*03AL | 7 | 25 | 3.45. 5 | 52.6 | 160.7 | 4.9 | 3.7 | 4.2 | KAM | 33 | D | 16 | P |
| KAM*206*08AL | 7 | 25 | 8.12.34 | 53.0 | 160.0 | 3.7 | 2.5 | 3.0 | KAM | 33 | D | 16 | L |
| KUR*206*08AL | 7 | 25 | 8.35.19 | 44.0 | 147.0 | 4.0 | -- | -- | KUR | 33 | ND | 12 | L |
| KUR*213*02AL | 8 | 1 | 2. 6. 7 | 50.4 | 156.8 | 5.6 | 4.5 | 4.5 | KAM | 20 | D | 14 | P |
| KUR*214*02OC | 8 | 2 | 2.57.24 | 50.8 | 158.1 | 3.6 | -- | -- | KAM | 33 | ND | 16 | L |
| HOK*214*07AL | 8 | 2 | 7.24.57 | 41.4 | 143.5 | 6.6 | 6.1 | 6.7 | --- | 51 | D | 18 | P |
| KYU*214*13AL | 8 | 2 | 13.59.41 | 33.0 | 130.9 | 3.6 | -- | -- | --- | 33 | ND | 17 | L |
| KUR*216*08AL | 8 | 4 | 8.58.16 | 41.8 | 141.5 | 3.7 | 2.8 | 2.7 | --- | 33 | D | 9 | L |
| KAM*217*01AL | 8 | 5 | 1. 5.57 | 50.0 | 156.8 | 3.7 | -- | -- | KAM | 33 | ND | 13 | L |
| SIN*219*15AL | 8 | 7 | 15.21.53 | 36.1 | 77.7 | 4.8 | 4.9 | 4.4 | CA | 33 | D | 10 | P |
| SIN*221*01AL | 8 | 9 | 1. 3.17 | 42.1 | 83.4 | 4.2 | 3.3 | 3.0 | CA | 33 | D | 12 | P |
| IRA*221*02OF | 8 | 9 | 2.54.37 | 36.2 | 52.7 | 5.2 | 5.1 | 4.9 | CSP | 27 | D | 17 | P |
| KUR*224*22AL | 8 | 12 | 22.55.28 | 47.0 | 150.0 | 3.9 | -- | -- | KUR | 33 | ND | 13 | L |
| KAM*225*00AL | 8 | 13 | 0.34.44 | 49.0 | 156.0 | 3.7 | -- | -- | KAM | 33 | ND | 13 | L |
| KUR*225*06AL | 8 | 13 | 6.15.57 | 46.0 | 151.0 | 4.1 | 2.4 | 2.3 | KUR | 33 | D | 13 | L |
| KUR*226*14AL | 8 | 14 | 14.47.57 | 48.0 | 153.0 | 3.8 | )2.5 | )2.5 | KUR | 33 | D | 12 | L |
| KUR*230*23AL | 8 | 18 | 23.27.16 | 43.1 | 145.8 | 3.6 | )2.9 | 4.1 | KUR | 33 | D | 6 | L |

COMPLETE LIST OF EVENTS USED IN ALPA EVALUATION
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| Event Name | Mo | Day | Origin Time | Lat °N | Long °E | $m_b$ | $(M_s)_R$ | $(M_s)_L$ | Reg | D | Det | NS | IS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| KUR*233*04AL | 8 | 21 | 4.21.46 | 40.9 | 143.2 | 3.8 | -- | -- | --- | 33 | ND | 12 | L |
| NRS*233*19AL | 8 | 21 | 19.34.23 | 81.9 | 118.9 | 4.6 | 3.9 | 3.3 | --- | 33 | D | 13 | P |
| KUR*234*02AL | 8 | 22 | 2.46.19 | 43.6 | 144.1 | 4.1 | )2.6 | -- | --- | 33 | ND | 12 | L |
| CRS*236*1600 | 8 | 24 | 16.33.23 | 52.2 | 91.4 | 5.2 | 4.7 | 4.8 | --- | 33 | D | 15 | P |
| IRA*237*0000 | 8 | 25 | 0.30.45 | 28.2 | 52.3 | 4.1 | )2.9 | )2.9 | SIR | 33 | D | 15 | P |
| SIN*237*0600 | 8 | 25 | 6.15.23 | 40.5 | 77.2 | 4.4 | 2.7 | 2.9 | CA | 15 | D | 11 | L |
| UKR*238*1500 | 8 | 26 | 15.17.22 | 45.4 | 36.7 | 4.1 | )2.7 | -- | --- | 12 | ND | 10 | L |
| SAK*248*18AL | 9 | 5 | 18.35.25 | 46.5 | 141.2 | 7.1 | 6.4 | 6.1 | --- | 9 | D | 18 | P |
| SAK*251*11AL | 9 | 8 | 11.48.23 | 46.4 | 141.1 | 5.9 | 6.0 | 6.2 | --- | 6 | D | 19 | P |
| SAK*251*16AL | 9 | 8 | 16.59.53 | 46.3 | 140.9 | 5.9 | 5.8 | 5.9 | --- | 16 | D | 18 | P |
| TUR*251*22AL | 9 | 8 | 22.35.16 | 41.0 | 44.0 | 4.8 | 4.1 | 3.7 | CSP | 33 | D | 15 | P |
| FRS*256*14AL | 9 | 13 | 14.26. 0 | 52.0 | 134.0 | 3.7 | 2.7 | 2.7 | --- | -- | D | 15 | L |
| CHI*258*11AL | 9 | 15 | 11.22.43 | 34.0 | 101.0 | 4.2 | )3.0 | -- | CA | -- | ND | 15 | N |
| TAD*259*10AL | 9 | 16 | 10.59.27 | 40.0 | 68.0 | 4.2 | )3.0 | -- | CA | -- | ND | 12 | N |
| CAU*262*06AL | 9 | 19 | 6.44.40 | 43.0 | 47.0 | 4.4 | )2.5 | )2.9 | CSP | -- | ND | 16 | L |
| WRS*262*11AL | 9 | 19 | 11. 0. 7 | 58.0 | 41.0 | 4.5 | )2.7 | )2.9 | --- | 33 | ND | 16 | P |
| CAU*263*08AL | 9 | 20 | 8. 3. 0 | 43.0 | 33.0 | 4.2 | )3.2 | -- | --- | -- | ND | 16 | L |
| CHR*266*21RT | 9 | 23 | 21. 8. 0 | 53.0 | 120.0 | 4.2 | 3.7 | 2.9 | --- | -- | D | 14 | L |
| NVZ*270*05AL | 9 | 27 | 5.59.55 | 73.0 | 55.0 | 6.4 | 4.6 | 4.4 | --- | 00 | D | 18 | XP |
| SAK*270*19AL | 9 | 27 | 19. 1.45 | 46.4 | 141.1 | 5.9 | 5.6 | 5.8 | --- | 21 | D | 19 | P |
| KAZ*273*12AL | 9 | 30 | 12.43.45 | 50.0 | 88.0 | 4.5 | 3.7 | 3.2 | --- | -- | D | 16 | N |
| TAD*274*16AL | 10 | 1 | 16.27.48 | 39.0 | 70.0 | 4.9 | 3.7 | 4.0 | CA | 36 | D | 15 | P |
| WRS*277*10AL | 10 | 4 | 10. 0.42 | 62.0 | 47.0 | 5.1 | 3.0 | )2.8 | --- | 13 | D | 17 | XP |
| TIB*278*05AL | 10 | 5 | 5.29.48 | 33.0 | 93.0 | 4.2 | 3.0 | )2.9 | CA | -- | D | 14 | N |
| SIN*281*09AL | 10 | 8 | 9.20.15 | 41.0 | 79.0 | 4.4 | 3.1 | )2.9 | CA | -- | D | 16 | L |
| EKZ*282*06AL | 10 | 9 | 6. 2.57 | 50.0 | 78.0 | 5.4 | )2.9 | )3.1 | EKZ | 00 | D | 10 | XP |
| CHI*283*05AL | 10 | 10 | 5.53.55 | 34.0 | 95.0 | 4.4 | 3.5 | 3.5 | CA | -- | D | 11 | N |
| CAU*283*09AL | 10 | 10 | 9. 5.45 | 43.0 | 44.0 | 4.0 | 2.8 | 2.8 | CSP | -- | D | 12 | L |

## COMPLETE LIST OF EVENTS USED IN ALPA EVALUATION
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| Event Name | Mo | Day | Origin Time | Lat °N | Long °E | $m_b$ | $(M_s)_R$ | $(M_s)_L$ | Reg | D | Det | NS | IS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| IRA*288*14AL | 10 | 15 | 14.19.32 | 37.0 | 55.0 | 4.7 | 5.1 | 3.6 | CSP | 39 | D | 16 | P |
| CAU*288*17AL | 10 | 15 | 17. 8. 6 | 41.0 | 49.0 | 4.9 | 3.7 | 3.3 | CSP | 33 | D | 14 | P |
| EKZ*294*06AL | 10 | 21 | 6. 2.57 | 50.0 | 78.0 | 5.6 | 3.1 | 3.0 | EKZ | 00 | D | 14 | XP |
| WRS*295*05AL | 10 | 22 | 5. 0. 0 | 52.0 | 55.0 | 5.3 | )2.7 | )2.8 | --- | 6 | D | 16 | XP |
| KGZ*301*13AL | 10 | 28 | 13.30.57 | 41.9 | 72.4 | 5.5 | 4.8 | 4.7 | CA | 22 | D | 13 | P |
| TIR*302*17AL | 10 | 29 | 17.16.52 | 34.0 | 86.0 | 5.0 | 3.7 | 3.6 | CA | -- | D | 14 | N |
| EKZ*333*06R2 | 11 | 29 | 6. 2.57 | 50.0 | 73.0 | 5.5 | 3.1 | 3.1 | EKZ | 00 | D | 14 | XP |
| WKZ*356*06R2 | 12 | 22 | 6.59.56 | 47.9 | 48.2 | 6.0 | 3.5 | 3.2 | --- | 00 | D | 9 | XP |
| EKZ*364*06R2 | 12 | 30 | 6.20.57 | 49.7 | 78.1 | 5.8 | 3.5 | 3.3 | EKZ | 00 | D | 17 | XP |
| SIR-001-15TD | 1 | 1 | 15. 4.19 | 59.7 | 153.8 | 4.1 | )2.4 | 2.6 | --- | -- | D | 17 | L |
| KUR-001-18AL | 1 | 1 | 18.13.54 | 49.4 | 156.5 | 4.0 | 2.4 | 2.8 | KAM | 50 | D | 17 | L |
| KUR-002-05AL | 1 | 2 | 5.37.25 | 46.1 | 146.2 | 4.0 | )2.5 | )2.5 | --- | 33 | ND | 18 | L |
| GRF-002-09AL | 1 | 2 | 9.17.53 | 37.9 | 20.7 | 4.2 | )3.0 | )3.0 | GT | 45 | ND | 18 | P |
| SIN-002-10AL | 1 | 2 | 10.27.35 | 41.8 | 84.5 | 5.2 | 4.2 | 4.0 | CA | 19 | D | 18 | P |
| KAM-003-06AL | 1 | 3 | 6.36.38 | 51.6 | 159.4 | 4.8 | 3.2 | 3.9 | KAM | N | D | 18 | P |
| ERS-003-23AL | 1 | 3 | 23.40.37 | 58.8 | 130.8 | 3.4 | )2.6 | )2.7 | --- | 16 | ND | 15 | L |
| KAM-004-02AL | 1 | 4 | 2.29.18 | 55.6 | 161.2 | 4.3 | 2.6 | )2.7 | KAM | 33 | D | 18 | L |
| KAM-004-10AL | 1 | 4 | 10.42.31 | 55.6 | 163.8 | 4.4 | )2.4 | )2.9 | KAM | 33 | ND | 18 | L |
| CPS-004-13OX | 1 | 4 | 13.13. 1 | 60.0 | 101.7 | 3.8 | 3.1 | 3.2 | CA | -- | D | 11 | L |
| KUR-005-02AL | 1 | 5 | 2.16.10 | 43.8 | 147.2 | 4.5 | 2.7 | 2.8 | KUR | N | D | 18 | P |
| AUS-005-04AL | 1 | 5 | 4.57.41 | 47.8 | 16.2 | 4.0 | )3.1 | )2.9 | --- | 11 | ND | 15 | P |
| KOM-005-14AL | 1 | 5 | 14.26.46 | 56.6 | 169.4 | 4.0 | )2.0 | 2.5 | --- | 33 | D | 15 | L |
| TWN-006-06AL | 1 | 6 | 6.33.34 | 23.3 | 123.4 | 4.7 | 3.4 | 3.4 | TWN | -- | D | 17 | P |
| IRA-006-09OX | 1 | 6 | 9.41.33 | 30.3 | 50.5 | 5.2 | 3.5 | 3.3 | SIR | 41 | D | 12 | P |
| SWR-007-20OC | 1 | 7 | 20.37.32 | 44.1 | 45.1 | 4.2 | )3.0 | )3.0 | CSP | 33 | ND | 13 | L |
| TWN-008-14OX | 1 | 8 | 14.32.27 | 23.0 | 119.0 | 4.6 | 3.9 | 4.1 | TWN | -- | D | 12 | N |
| KOM-009-03Q1 | 1 | 9 | 3.23. 6 | 54.4 | 164.4 | 3.6 | )2.6 | )2.7 | KAM | 33 | ND | 17 | L |
| KAM-009-14Q1 | 1 | 9 | 14. 0.59 | 55.7 | 163.6 | 4.3 | 3.2 | 3.4 | KAM | -- | D | 6 | L |

COMPLETE LIST OF EVENTS USED IN ALPA EVALUATION
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| Event Name | Mo | Day | Origin Time | Lat °N | Long °E | $m_b$ | $(M_s)_R$ | $(M_s)_L$ | Reg | D | Det | NS | IS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| KUR-009-1401 | 1 | 9 | 14.47.46 | 45.1 | 148.4 | 3.8 | )3.2 | )3.4 | KUR | 33 | ND | 8 | L |
| PIP-010-050X | 1 | 10 | 5.23.52 | 20.9 | 120.4 | 5.0 | 3.8 | 3.8 | TWN | 32 | D | 7 | P |
| KOM-011-08AL | 1 | 11 | 8.54.34 | 54.7 | 168.2 | 3.9 | M2.4 | )2.2 | --- | 28 | D | 6 | L |
| KUR-011-15AL | 1 | 11 | 15.46.45 | 43.4 | 147.8 | 4.0 | 2.8 | 3.0 | KUR | 33 | D | 6 | L |
| CRE-012-130X | 1 | 12 | 13.51.20 | 35.0 | 23.5 | 4.9 | 4.2 | 3.7 | GT | 48 | D | 8 | P |
| KAM-012-20AL | 1 | 12 | 20.20.15 | 55.6 | 163.9 | 4.8 | 4.0 | 4.2 | KAM | 33 | D | 8 | P |
| SIB-013-1706 | 1 | 13 | 17.24. 7 | 61.9 | 147.1 | 5.3 | 4.6 | 5.0 | --- | 33 | D | 8 | P |
| SIB-014-03AL | 1 | 14 | 3.20.20 | 67.5 | 171.5 | 3.9 | 2.8 | 3.3 | --- | -- | D | 13 | P |
| KUR-015-00AL | 1 | 15 | 0.58.33 | 49.6 | 155.0 | 3.9 | )2.4 | )2.4 | KAM | 33 | ND | 8 | L |
| FRS-015-18AL | 1 | 15 | 18. 7.58 | 57.4 | 120.7 | 4.7 | 2.9 | 3.6 | --- | 13 | D | 8 | P |
| KAM-016-04AL | 1 | 16 | 4.38.16 | 55.6 | 162.5 | 3.8 | 2.5 | 2.4 | KAM | 33 | D | 9 | L |
| KAM-016-11AL | 1 | 16 | 11. 0.49 | 55.6 | 163.2 | 3.9 | )2.6 | )2.4 | KAM | 25 | ND | 8 | L |
| CRE-017-05AL | 1 | 17 | 5.54.20 | 34.5 | 26.5 | 4.1 | )3.3 | )3.3 | GT | 33 | ND | 8 | L |
| IRA-018-2101 | 1 | 18 | 21.12. 2 | 27.5 | 48.7 | 4.9 | 3.8 | 3.7 | CSP | N | D | 9 | P |
| DOD-020-02AL | 1 | 20 | 2.15. 7 | 36.6 | 27.1 | 4.8 | 3.6 | 3.4 | GT | 33 | D | 16 | P |
| KUR-022-01AL | 1 | 22 | 1.41.24 | 50.0 | 152.0 | 4.2 | 2.4 | 2.5 | --- | -- | D | 18 | N |
| TUR-022-17AL | 1 | 22 | 17.17.31 | 37.6 | 29.9 | 4.4 | )3.2 | )3.3 | GT | 13 | ND | 12 | P |
| YUN-023-02TD | 1 | 23 | 2. 6. 1 | 23.6 | 102.7 | 5.2 | 5.0 | 5.4 | --- | 33 | D | 14 | P |
| KAM-023-08AL | 1 | 23 | 8.30.47 | 52.0 | 158.0 | 4.2 | 2.5 | 2.8 | KAM | -- | D | 12 | N |
| KAM-024-12AL | 1 | 24 | 12.39.22 | 51.7 | 159.0 | 4.0 | 2.6 | 2.8 | KAM | -- | D | 13 | L |
| KAM-025-10AL | 1 | 25 | 10. 2.40 | 53.9 | 160.9 | 4.6 | 3.4 | 3.3 | KAM | N | D | 17 | P |
| ITY-025-20AL | 1 | 25 | 20.24.39 | 43.8 | 13.4 | *4.2 | 3.6 | 3.2 | GT | N | D | 16 | P |
| TWN-025-21AL | 1 | 25 | 21. 3. 0 | 22.5 | 122.2 | 4.8 | 3.4 | 3.3 | TWN | 35 | D | 17 | P |
| TWN-025-23AL | 1 | 25 | 23. 0.39 | 22.3 | 122.4 | 4.6 | 3.6 | 3.9 | TWN | 24 | D | 17 | P |
| KOM-026-09AL | 1 | 26 | 9.14.16 | 55.8 | 164.7 | 3.8 | 2.7 | 2.4 | KAM | -- | D | 16 | L |
| CRE-026-12AL | 1 | 26 | 12.54.39 | 34.5 | 25.5 | 4.0 | )3.0 | )3.2 | GT | 33 | ND | 15 | L |
| KUR-026-15AL | 1 | 26 | 15.56.27 | 48.9 | 155.9 | 4.8 | 2.8 | 3.0 | KAM | 50 | D | 16 | L |
| KAM-027-14AL | 1 | 27 | 14. 6.46 | 55.4 | 163.6 | 3.8 | 2.4 | )2.5 | KAM | 33 | D | 15 | L |

COMPLETE LIST OF EVENTS USED IN ALPA EVALUATION
(PAGE 9 OF 20)

| Event Name | Mo | Day | Origin Time | Lat °N | Long °E | $m_b$ | $(M_s)_R$ | $(M_s)_L$ | Reg | D | Det | NS | IS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| KAM-027-20AL | 1 | 27 | 20.37.29 | 55.7 | 162.3 | 3.8 | 2.8 | 3.4 | KAM | 40 | D | 17 | L |
| ECS-028-04AL | 1 | 28 | 4.22.28 | 27.5 | 126.5 | 4.4 | 3.0 | 3.4 | --- | 33 | D | 16 | L |
| PAK-028-10OC | 1 | 28 | 10.26.54 | 26.6 | 66.3 | 5.9 | 4.1 | 4.1 | --- | 33 | D | 14 | P |
| ARA-028-13AL | 1 | 28 | 13.37.28 | 15.0 | 47.0 | 4.0 | )3.2 | )3.3 | --- | -- | ND | 17 | N |
| ERS-028-21AL | 1 | 28 | 21.54. 4 | 45.0 | 136.0 | 4.0 | )2.6 | )2.7 | --- | -- | ND | 16 | N |
| IRA-029-09AL | 1 | 29 | 9.50.58 | 29.0 | 62.0 | 3.9 | )3.2 | 3.1 | --- | -- | D | 17 | N |
| CHI-030-03AL | 1 | 30 | 3.56.41 | 40.9 | 120.2 | 3.9 | 3.5 | 3.8 | --- | 33 | D | 13 | L |
| KAM-032-10AL | 2 | 1 | 10.16. 9 | 55.8 | 162.8 | 4.1 | 2.4 | 2.7 | KAM | -- | D | 14 | L |
| KAM-033-04AL | 2 | 2 | 4.26.59 | 55.7 | 162.0 | 3.7 | )2.1 | )2.2 | KAM | -- | ND | 13 | L |
| KUR-033-09AL | 2 | 2 | 9.58.51 | 46.3 | 146.4 | 3.6 | )2.6 | )2.7 | --- | -- | ND | 14 | L |
| KUR-033-17AL | 2 | 2 | 17.56.39 | 50.7 | 160.1 | 3.6 | )2.2 | 2.5 | KAM | -- | D | 14 | L |
| GRE-033-21AL | 2 | 2 | 21.19.49 | 38.9 | 21.2 | 4.6 | 3.4 | 3.2 | GT | 44 | D | 15 | P |
| CAU-034-02AL | 2 | 3 | 2.29.22 | 40.7 | 48.4 | 5.1 | 4.4 | 4.2 | CSP | 39 | D | 11 | P |
| YUN-034-07OD | 2 | 3 | 7.22.49 | 23.4 | 102.4 | 4.5 | 4.3 | 4.8 | --- | -- | D | 15 | P |
| ITY-035-02AL | 2 | 4 | 2.42.19 | 43.8 | 13.3 | *4.5 | 3.7 | 3.5 | GT | 25 | D | 15 | P |
| BKL-035-03TE | 2 | 4 | 3.34.56 | 51.4 | 118.0 | 4.2 | 3.0 | 3.0 | --- | -- | D | 11 | L |
| ITY-035-04OC | 2 | 4 | 4.40.50 | 43.9 | 13.2 | 4.8 | )3.0 | )3.0 | GT | 33 | ND | 13 | P |
| KUR-035-07OC | 2 | 4 | 7.51.14 | 48.3 | 154.2 | 4.8 | 3.2 | 2.9 | --- | -- | D | 14 | L |
| ITY-035-09AL | 2 | 4 | 9.18.32 | 43.9 | 13.2 | 4.4 | 3.3 | 3.1 | GT | 23 | D | 15 | P |
| ITY-035-17AL | 2 | 4 | 17.19.52 | 43.8 | 13.3 | *4.1 | 3.4 | )3.2 | GT | 23 | D | 16 | P |
| ITY-035-18QX | 2 | 4 | 18.17.30 | 43.8 | 13.4 | *4.3 | 3.0 | 2.9 | GT | 32 | D | 16 | P |
| ITY-035-19OC | 2 | 4 | 19. 2.56 | 43.8 | 13.3 | *4.1 | 3.0 | 2.8 | GT | 33 | D | 15 | P |
| ITY-036-03AL | 2 | 5 | 3.49.45 | 43.2 | 13.7 | *3.7 | )3.0 | )2.8 | GT | 33 | ND | 15 | P |
| ITY-036-05AL | 2 | 5 | 5. 5.51 | 43.7 | 13.5 | *4.0 | 3.0 | )2.8 | GT | 33 | D | 14 | P |
| ITY-036-07AL | 2 | 5 | 7. 8.13 | 43.9 | 13.3 | *4.5 | 3.1 | 2.9 | GT | 33 | D | 14 | P |
| ITY-036-15AL | 2 | 5 | 15.14.49 | 43.7 | 13.4 | *4.2 | 3.5 | 3.0 | GT | 35 | D | 15 | P |
| TIB-037-04AL | 2 | 6 | 4.29. 5 | 29.0 | 89.0 | 4.1 | )3.1 | )3.3 | CA | -- | ND | 12 | N |
| SIN-037-07AL | 2 | 6 | 7.30.11 | 41.6 | 82.2 | 4.7 | 3.2 | )3.2 | CA | 33 | D | 14 | P |

## COMPLETE LIST OF EVENTS USED IN ALPA EVALUATION
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| Event Name | Mo | Day | Origin Time | Lat °N | Long °E | $m_b$ | $(M_s)_R$ | $(M_s)_L$ | Reg | D | Det | NS | IS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| EKZ-037-08AL | 2 | 6 | 8. 3.43 | 46.0 | 80.0 | 4.3 | )3.0 | )3.2 | CA | -- | ND | 14 | N |
| KAM-038-070C | 2 | 7 | 7.49.48 | 52.3 | 160.1 | 4.8 | 3.1 | 3.8 | KAM | 60 | D | 12 | P |
| PIP-039-03AL | 2 | 8 | 3.37.52 | 19.3 | 122.0 | 5.7 | 4.8 | 4.8 | TWN | 50 | D | 14 | P |
| TWN-039-15TD | 2 | 9 | 15.42.55 | 22.7 | 122.6 | 4.8 | 3.5 | 3.5 | TWN | 33 | D | 10 | P |
| EKZ-041-05AL | 2 | 10 | 5. 2.57 | 50.0 | 78.9 | 5.5 | 2.7 | )2.8 | EKZ | 00 | D | 15 | YP |
| IRA-041-09TD | 2 | 10 | 9. 4. 9 | 29.6 | 50.9 | 3.9 | 3.4 | 3.3 | SIR | 33 | D | 10 | P |
| IRA-041-160C | 2 | 10 | 16.40.16 | 29.5 | 50.9 | 4.1 | 3.3 | 3.5 | SIR | 49 | D | 16 | P |
| SIN-042-050D | 2 | 11 | 5.55.46 | 39.9 | 77.4 | 4.9 | 4.0 | 3.9 | CA | 23 | D | 8 | P |
| TIB-042-12AL | 2 | 11 | 12.20.43 | 29.0 | 87.0 | 4.3 | 3.1 | 3.5 | CA | -- | D | 15 | N |
| KOM-042-13AL | 2 | 11 | 13.58.49 | 55.5 | 165.2 | 3.9 | 2.2 | 2.4 | KAM | -- | D | 15 | L |
| KAM-042-21AL | 2 | 11 | 21.36.17 | 56.1 | 162.9 | 4.6 | 3.6 | 3.9 | KAM | 44 | D | 15 | P |
| KUR-044-05AL | 2 | 13 | 5.24.57 | 43.5 | 147.0 | 3.8 | )2.8 | )2.9 | KUR | -- | ND | 12 | L |
| KUR-046-16AL | 2 | 15 | 16.45.22 | 45.0 | 153.0 | 4.1 | 2.5 | 2.4 | KUR | -- | D | 13 | L |
| GRE-047-00AL | 2 | 16 | 0.42.24 | 36.9 | 24.2 | 4.5 | )3.0 | )3.2 | GT | 33 | ND | 16 | P |
| SIN-047-230C | 2 | 16 | 23.19.20 | 41.7 | 80.7 | 4.8 | 3.6 | 3.3 | CA | 29 | D | 12 | P |
| KUR-049-140C | 2 | 18 | 14.30.23 | 46.6 | 151.0 | 3.7 | 2.4 | 2.6 | KUR | -- | D | 13 | L |
| KUR-049-18AL | 2 | 18 | 18. 2.34 | 43.6 | 147.8 | 4.7 | 3.1 | 3.6 | KUR | 36 | D | 16 | P |
| KAM-050-070C | 2 | 19 | 6.48.12 | 55.1 | 161.5 | 4.0 | 2.4 | 2.4 | KAM | 33 | D | 13 | L |
| KAM-052-22AL | 2 | 21 | 22. 0.59 | 54.4 | 161.3 | 4.8 | 3.6 | 3.6 | KAM | N | D | 15 | I |
| YUG-052-230D | 2 | 21 | 23. 2.56 | 41.0 | 22.3 | 4.0 | )3.0 | )2.8 | GT | 33 | ND | 13 | I |
| KAM-053-040C | 2 | 22 | 3.38.29 | 56.0 | 156.0 | 3.4 | 2.4 | 2.5 | --- | 33 | D | 14 | J |
| HIN-053-080C | 2 | 22 | 8.14.26 | 36.6 | 68.6 | 4.0 | )2.9 | )2.8 | CA | N | ND | 14 | J |
| KUR-054-030C | 2 | 23 | 3. 7. 4 | 43.7 | 148.4 | 4.8 | 3.4 | 3.9 | KUR | 41 | D | 12 | I |
| KUR-054-030X | 2 | 23 | 3.21.31 | 44.2 | 148.4 | 4.7 | 3.4 | 3.8 | KUR | 40 | D | 18 | I |
| KRL-054-030X | 2 | 23 | 3.42.41 | 43.9 | 148.3 | 4.9 | 3.3 | 3.9 | KUR | 39 | D | 17 | I |
| KUR-054-050C | 2 | 23 | 5.11. 9 | 45.0 | 150.0 | 3.7 | 2.3 | )2.2 | KUR | N | D | 14 | J |
| LOM-054-09AL | 2 | 23 | 9.46.50 | 86.0 | 139.0 | 3.7 | )2.2 | )2.0 | --- | N | ND | 13 | J |
| WPA-054-14AL | 2 | 23 | 14. 0.49 | 38.1 | 71.7 | 4.3 | )2.8 | )3.0 | CA | N | ND | 15 | I |

COMPLETE LIST OF EVENTS USED IN ALPA EVALUATION
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| Event Name | Mo | Day | Origin Time | Lat °N | Long °E | $m_b$ | $(M_s)_R$ | $(M_s)_L$ | Reg | D | Det | NS | IS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| KAM-055-00AL | 2 | 24 | 0.38. 0 | 54.0 | 156.0 | 4.5 | 2.7 | 2.8 | --- | N | D | 16 | J |
| KUR-055-10QX | 2 | 24 | 10.19.37 | 48.9 | 155.7 | 5.0 | 4.0 | 4.1 | KAM | N | D | 14 | I |
| KUR-055-180C | 2 | 24 | 18.17.34 | 49.0 | 158.0 | 3.5 | )2.5 | )2.6 | KAM | N | ND | 14 | J |
| KUR-056-200C | 2 | 25 | 19.59.29 | 46.0 | 147.0 | 3.8 | )2.4 | )2.4 | --- | N | ND | 12 | J |
| WRS-056-220C | 2 | 25 | 22.34.49 | 50.0 | 38.0 | 3.7 | )2.7 | (2.7 | --- | N | D | 15 | J |
| KUR-056-23AL | 2 | 25 | 22.43. 7 | 49.2 | 156.0 | 4.0 | 2.5 | 2.7 | KAM | N | D | 18 | I |
| KUR-057-02QX | 2 | 26 | 2.12.57 | 49.2 | 156.2 | 4.9 | 4.0 | 4.1 | KAM | N | D | 16 | I |
| KUR-057-06AL | 2 | 26 | 5.58.22 | 46.8 | 152.6 | 4.9 | 2.9 | 3.0 | KUR | N | D | 16 | I |
| ERU-057-15AL | 2 | 26 | 15. 6.42 | 53.3 | 138.7 | 3.8 | 2.5 | 2.6 | --- | N | D | 15 | I |
| OKH-057-19AL | 2 | 26 | 18.32.26 | 51.0 | 149.0 | 4.0 | )2.2 | )2.3 | --- | N | ND | 13 | J |
| YUN-057-19AL | 2 | 26 | 18.56.13 | 27.1 | 100.9 | 4.7 | 3.9 | 4.5 | --- | N | D | 14 | I |
| USM-057-23AL | 2 | 26 | 23.31.10 | 50.6 | 97.3 | 5.3 | 4.4 | 4.7 | --- | N | D | 15 | I |
| LOM-058-080C | 2 | 27 | 8.42.59 | 88.0 | -74.0 | 3.3 | )2.3 | )2.3 | --- | N | ND | 11 | I |
| FJL-058-10QX | 2 | 27 | 10. 3. 3 | 87.0 | 53.5 | 4.9 | 4.0 | 3.5 | --- | N | D | 14 | I |
| LOM-058-110D | 2 | 27 | 11. 3.19 | 90.0 | -95.0 | 3.5 | )2.5 | )2.3 | --- | N | ND | 10 | I |
| SEV-058-17QY | 2 | 27 | 17.50.25 | 86.2 | 77.2 | 4.4 | 2.9 | 2.5 | --- | N | D | 1[illegible] | I |
| AUB-059-05QX | 2 | 28 | 5.18.56 | 36.7 | 71.4 | 4.2 | )3.2 | 3.6 | CA | N | D | 13 | I |
| KAM-059-11AL | 2 | 28 | 11.35.31 | 56.0 | 163.0 | 4.1 | (2.5 | )2.7 | KAM | N | D | 10 | I |
| KAM-059-14AL | 2 | 28 | 14.49.55 | 54.1 | 160.7 | 3.3 | )2.2 | 2.7 | KAM | N | D | 9 | I |
| CRS-059-15QX | 2 | 28 | 15.44.20 | 51.8 | 90.2 | 3.9 | 2.9 | 3.0 | --- | N | D | 9 | I |
| IRA-059-17AL | 2 | 28 | 16.44.58 | 29.5 | 50.7 | 4.4 | 3.2 | 3.1 | SIR | 55 | D | 13 | I |
| KOM-059-20QX | 2 | 28 | 20. 4. 0 | 56.1 | 164.2 | 3.6 | 3.0 | 3.4 | KAM | N | D | 11 | I |
| IRQ-060-08AL | 2 | 29 | 8. 2.51 | 32.8 | 46.6 | 4.0 | )3.1 | )3.0 | CSP | N | ND | 12 | I |
| LOM-060-08AL | 2 | 29 | 8. 7.20 | 89.0 | -51.0 | 3.4 | 2.3 | 2.4 | --- | N | D | 13 | I |
| SIN-060-19AL | 2 | 29 | 19.47.58 | 39.0 | 74.0 | 4.0 | )3.1 | )3.2 | CA | 33 | ND | 12 | J |
| BTN-061-05AL | 3 | 1 | 5. 6.22 | 27.0 | 89.0 | 3.9 | )3.2 | )3.3 | CA | N | ND | 11 | J |
| KAM-061-16AL | 3 | 1 | 16.58.59 | 51.0 | 162.0 | 3.5 | 2.3 | 2.3 | --- | N | D | 14 | J |
| KOM-062-060C | 3 | 2 | 6.17.29 | 53.0 | 167.0 | 3.6 | )2.1 | )2.2 | --- | N | ND | 15 | I |

## COMPLETE LIST OF EVENTS USED IN ALPA EVALUATION
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| Event Name | Mo | Day | Origin Time | Lat °N | Long °E | $m_b$ | $(M_s)_R$ | $(M_s)_L$ | Reg | D | Det | NS | IS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| IRO-062-140X | 3 | 2 | 14.10.13 | 31.6 | 42.1 | 4.0 | C3.1 | C3.0 | CSP | N | D | 16 | I |
| KAM-063-00AL | 3 | 3 | 0.39.23 | 53.0 | 159.2 | 4.1 | 2.5 | 2.4 | KAM | N | D | 14 | I |
| LAP-063-050X | 3 | 3 | 5.26.53 | 77.8 | 116.7 | 3.8 | 2.2 | 2.7 | --- | N | D | 13 | I |
| KOM-063-08AL | 3 | 3 | 8.13.55 | 55.8 | 163.9 | 4.1 | 2.3 | 2.7 | KAM | N | D | 14 | I |
| YUG-063-210X | 3 | 3 | 21.26.51 | 44.7 | 18.4 | *4.4 | 3.2 | 3.2 | GT | 32 | D | 17 | I |
| KUR-063-23AL | 3 | 3 | 23.10.41 | 50.2 | 155.7 | 4.5 | 3.0 | 3.0 | KAM | N | D | 15 | I |
| SIN-064-04AL | 3 | 4 | 4. 0. 9 | 40.2 | 79.0 | 4.5 | 3.6 | 3.5 | CA | N | D | 15 | I |
| SIN-064-08AL | 3 | 4 | 8.22.16 | 42.1 | 83.3 | 4.4 | 3.4 | 3.3 | CA | N | D | 15 | I |
| YUG-064-14AL | 3 | 4 | 14.42. 5 | 41.0 | 21.0 | 3.6 | )2.9 | )2.9 | GT | N | ND | 10 | I |
| IND-065-19AL | 3 | 5 | 19. 7.43 | 21.0 | 73.0 | 4.0 | )2.8 | )2.8 | --- | N | ND | 15 | J |
| KAM-066-06AL | 3 | 6 | 6. 5. 8 | 53.5 | 160.9 | 3.9 | 2.4 | 2.3 | KAM | N | D | 17 | I |
| KUR-066-09AL | 3 | 6 | 9.59. 9 | 45.0 | 150.0 | 3.7 | )2.1 | )2.6 | KUR | N | ND | 15 | J |
| NCH-066-23AL | 3 | 6 | 23.17.53 | 40.0 | 103.0 | 4.5 | )2.6 | 2.9 | --- | N | D | 14 | J |
| YUG-067-050X | 3 | 7 | 5.21.21 | 43.0 | 21.0 | 2.7 | )3.1 | )2.9 | GT | N | ND | 16 | I |
| OKH-068-02AL | 3 | 8 | 2.38.11 | 51.2 | 151.9 | 4.2 | )2.5 | )2.7 | --- | N | ND | 6 | I |
| IRA-068-21AL | 3 | 8 | 21.49.11 | 27.6 | 56.7 | *4.6 | 3.7 | 4.0 | SIR | 45 | D | 6 | I |
| EKZ-070-04AL | 3 | 10 | 4.56.57 | 49.8 | 78.2 | 5.5 | 3.1 | 3.4 | EKZ | 00 | D | 11 | XI |
| KUR-070-06AL | 3 | 10 | 6.50.18 | 45.1 | 149.5 | 3.7 | 2.7 | 2.7 | KUR | N | D | 19 | I |
| ARC-071-06AL | 3 | 11 | 6.47. 7 | 82.7 | 143.3 | 3.6 | 3.0 | 2.6 | --- | N | D | 17 | I |
| KUR-073-02AL | 3 | 13 | 2.11. 5 | 49.0 | 153.0 | 3.8 | )2.2 | )2.4 | KAM | N | ND | 12 | I |
| KUR-073-09AL | 3 | 13 | 9.23.29 | 39.3 | 25.6 | 3.8 | C3.3 | )3.4 | GT | 47 | D | 9 | I |
| TIR-073-19AL | 3 | 13 | 19.27. 7 | 34.0 | 83.0 | 4.1 | )2.9 | )3.0 | CA | N | ND | 9 | J |
| KOR-074-15AL | 3 | 14 | 15.47.51 | 39.0 | 126.0 | 3.7 | )2.6 | 2.8 | --- | N | D | 13 | J |
| TIB-075-06AL | 3 | 15 | 6. 0.33 | 30.4 | 84.5 | 5.3 | -- | 4.0 | CA | 33 | D | 11 | I |
| SIN-076-21AL | 3 | 16 | 21.11.35 | 38.0 | 82.0 | 3.5 | )3.0 | )3.2 | CA | N | ND | 12 | J |
| KUR-077-07AL | 3 | 17 | 7.49. 2 | 49.0 | 156.2 | 5.2 | 3.8 | 3.9 | KAM | 33 | D | 14 | I |
| TAD-077-09AL | 3 | 17 | 9.17.11 | 40.1 | 69.7 | 5.2 | 4.6 | 4.2 | CA | 26 | D | 14 | I |
| IRA-077-170C | 3 | 17 | 17.11.28 | 28.0 | 54.0 | 3.9 | )3.0 | )3.0 | SIR | N | ND | 10 | J |

## COMPLETE LIST OF EVENTS USED IN ALPA EVALUATION
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| Event Name | Mo | Day | Origin Time | Lat °N | Long °E | $m_b$ | $(M_s)_R$ | $(M_s)_L$ | Reg | D | Det | NS | IS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| KIR-077-23OC | 3 | 17 | 23.33.37 | 32.0 | 75.0 | 3.5 | (2.8 | (2.9 | CA | N | D | 12 | J |
| KAM-078-13AL | 3 | 19 | 13.52.14 | 57.0 | 163.0 | 3.6 | M2.1 | )2.2 | KAM | N | D | 14 | J |
| KAM-078-18OC | 3 | 19 | 18.29.33 | 50.6 | 156.7 | 4.7 | 3.1 | 2.9 | KAM | N | D | 12 | I |
| OKH-078-19AL | 3 | 19 | 19.17.25 | 54.0 | 150.0 | 3.7 | )2.2 | )2.4 | --- | N | ND | 11 | J |
| CAU-079-03AL | 3 | 19 | 3.34.31 | 42.7 | 38.1 | 3.9 | )3.0 | )2.9 | --- | N | ND | 12 | I |
| TSK-080-10OX | 3 | 20 | 10.54.35 | 38.0 | 73.0 | 3.9 | )3.3 | )3.2 | CA | N | ND | 12 | I |
| SIN-080-21AL | 3 | 20 | 21.47.55 | 40.0 | 80.0 | 3.4 | )2.9 | )2.9 | CA | -- | ND | 12 | I |
| SIN-084-08OC | 3 | 24 | 8.11.53 | 42.9 | 87.4 | 5.0 | 4.0 | 3.5 | CA | N | D | 13 | P |
| EKZ-088-04AL | 3 | 28 | 4.21.57 | 49.7 | 78.2 | 5.2 | )2.7 | )2.8 | EKZ | 00 | ND | 8 | XP |
| KUR-153-00AL | 6 | 1 | 0.18.13 | 48.0 | 154.0 | 3.9 | M2.5 | M2.8 | --- | -- | D | 11 | L |
| CKZ-153-01AL | 6 | 1 | 1.23.26 | 52.0 | 70.0 | 3.6 | 2.8 | )2.9 | --- | -- | D | 13 | L |
| MON-153-11AL | 6 | 1 | 11.22.15 | 44.0 | 103.0 | 3.7 | 3.0 | )2.9 | --- | -- | D | 9 | N |
| KOM-153-21AL | 6 | 1 | 21.43.49 | 55.0 | 164.0 | 3.8 | 2.8 | 3.2 | KAM | -- | D | 8 | L |
| IRA-154-00AL | 6 | 2 | 0.12.13 | 30.0 | 53.0 | 4.1 | )3.2 | (3.2 | SIR | -- | D | 13 | N |
| KUR-154-01AL | 6 | 2 | 1.53. 7 | 50.0 | 152.0 | 3.8 | 2.9 | 2.9 | --- | -- | D | 13 | L |
| KZS-154-05AL | 6 | 2 | 5.11.13 | 43.0 | 81.0 | 3.5 | )2.9 | )2.9 | CA | -- | ND | 13 | N |
| SIN-154-06AL | 6 | 2 | 6.30.49 | 42.0 | 81.0 | 3.9 | 3.0 | 3.3 | CA | -- | D | 15 | N |
| TSI-154-16AL | 6 | 2 | 16.49.22 | 36.0 | 92.0 | 3.7 | 3.4 | 3.6 | CA | -- | D | 8 | N |
| CIN-154-20AL | 6 | 2 | 20.32.55 | 28.4 | 95.9 | 4.3 | )3.1 | )3.2 | CA | 33 | ND | 9 | P |
| RYU-155-02AL | 6 | 3 | 2.16.51 | 23.5 | 125.5 | *5.0 | 3.5 | 3.9 | TWN | 33 | D | 13 | P |
| IRA-155-08AL | 6 | 3 | 8.21.30 | 29.0 | 53.0 | 4.2 | 3.3 | 3.2 | SIP | -- | D | 14 | N |
| IRA-156-03AL | 6 | 4 | 3.37.49 | 30.0 | 54.0 | 4.2 | )2.9 | (2.8 | SIP | -- | D | 14 | N |
| KAM-156-07AL | 6 | 4 | 7.52.38 | 53.0 | 158.0 | 4.0 | 2.6 | 2.6 | KAM | -- | D | 15 | L |
| AGN-156-16AL | 6 | 4 | 16.29.34 | 39.4 | 26.2 | 4.1 | )3.0 | )3.1 | GT | 17 | ND | 6 | P |
| TSI-156-23AL | 6 | 4 | 23.22.18 | 33.0 | 97.0 | 4.5 | 3.1 | 3.6 | CA | -- | D | 13 | N |
| KAM-157-04AL | 6 | 5 | 4.12.54 | 56.2 | 163.1 | 4.3 | 2.7 | 3.2 | KAM | -- | D | 15 | P |
| IIO-157-11AL | 6 | 5 | 11.17.57 | 34.0 | 46.0 | 3.9 | )3.1 | )3.0 | CSP | -- | ND | 11 | N |
| PAK-157-11OC | 6 | 5 | 11.52.53 | 29.8 | 70.3 | 4.8 | 3.0 | )3.2 | CA | 27 | D | 6 | P |

## COMPLETE LIST OF EVENTS USED IN ALPA EVALUATION
## (PAGE 14 OF 20)

| Event Name | Mo | Day | Origin Time | Lat °N | Long °E | $m_b$ | $(M_s)_R$ | $(M_s)_L$ | Reg | D | Det | NS | IS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| FJL-157-19AL | 6 | 5 | 19. 0.12 | 86.5 | 38.9 | 4.5 | 3.1 | 2.5 | --- | N | D | 14 | L |
| KAM-158-10AL | 6 | 6 | 10.43.33 | 55.9 | 163.8 | 4.7 | 3.6 | 3.5 | KAM | 33 | D | 15 | P |
| FK7-159-010D | 6 | 7 | 1.27.57 | 49.8 | 78.2 | 5.5 | 3.4 | 3.1 | FK7 | 00 | D | 15 | XP |
| TWN-160-09AL | 6 | 8 | 9.14. 8 | 21.1 | 120.2 | 5.4 | 3.9 | 3.9 | TWN | 33 | D | 17 | P |
| TWN-160-10AL | 6 | 8 | 10.17.44 | 21.0 | 120.2 | 4.9 | 3.8 | C3.7 | TWN | 33 | D | 16 | P |
| TUR-160-12AL | 6 | 8 | 12.46.15 | 41.0 | 44.0 | 4.1 | )3.3 | )3.3 | CSP | -- | ND | 8 | L |
| CRE-161-07AL | 6 | 9 | 7.42.20 | 34.8 | 26.5 | 4.9 | 4.1 | 3.9 | GT | 33 | D | 16 | P |
| PAK-162-11AL | 6 | 10 | 11.29.11 | 28.2 | 66.5 | 4.5 | 3.8 | 3.8 | --- | 17 | D | 8 | P |
| KUR-162-19AL | 6 | 10 | 19.21.53 | 43.0 | 150.0 | 3.7 | )2.4 | )2.5 | KUR | -- | ND | 11 | L |
| IIQ-162-19AL | 6 | 10 | 19.31.42 | 32.9 | 46.3 | 4.0 | C3.3 | )3.1 | CSP | 33 | D | 11 | P |
| KAM-163-14AL | 6 | 11 | 14.14. 1 | 53.0 | 160.0 | 3.3 | )2.0 | )2.1 | KAM | -- | ND | 16 | L |
| IIQ-164-13AL | 6 | 12 | 13.34. 1 | 33.1 | 46.3 | 5.4 | 4.8 | 4.7 | CSP | 33 | D | 13 | P |
| IIQ-165-00AL | 6 | 13 | 0.55.37 | 33.1 | 46.3 | 5.1 | 4.2 | 4.1 | CSP | 27 | D | 9 | P |
| KAM-165-04AL | 6 | 13 | 4.53.30 | 55.0 | 162.0 | 3.8 | 2.3 | 2.8 | KAM | -- | D | 10 | L |
| ERS-165-100D | 6 | 13 | 10.45. 5 | 54.9 | 126.4 | 4.8 | 4.3 | 5.1 | --- | 33 | D | 14 | P |
| IIQ-166-04AL | 6 | 14 | 4.34.28 | 33.0 | 46.1 | 5.3 | 4.1 | 3.7 | CSP | 33 | D | 5 | P |
| KOM-166-10AL | 6 | 14 | 10.27.50 | 57.0 | 164.0 | 3.6 | )2.1 | 2.4 | KAM | -- | D | 6 | L |
| SIR-166-12AL | 6 | 14 | 12.35. 5 | 27.0 | 56.0 | 3.6 | )3.0 | C3.0 | SIR | -- | D | 6 | N |
| KAM-168-09AL | 6 | 16 | 9.54.41 | 56.0 | 161.0 | 4.1 | 2.4 | 2.7 | KAM | -- | D | 16 | L |
| IIQ-168-23AL | 6 | 16 | 23.22.27 | 34.0 | 46.0 | 3.7 | )2.9 | )2.9 | CSP | -- | ND | 9 | N |
| AUS-169-09AL | 6 | 17 | 9. 2.48 | 48.3 | 14.5 | *4.3 | )2.8 | )2.6 | --- | 33 | ND | 15 | P |
| TIB-170-04AL | 6 | 18 | 4.30.47 | 33.0 | 83.0 | 4.3 | 3.7 | 3.9 | CA | -- | D | 13 | N |
| KUR-170-09QC | 6 | 18 | 9.10.54 | 48.0 | 154.0 | 3.9 | M2.5 | )2.4 | --- | -- | D | 9 | L |
| TSK-170-09QC | 6 | 18 | 9.18.49 | 40.0 | 73.0 | 4.3 | M2.8 | M2.9 | CA | -- | D | 11 | L |
| TUR-170-22TD | 6 | 18 | 22.32.52 | 39.0 | 31.0 | 4.4 | )2.7 | )2.8 | GT | -- | ND | 9 | L |
| KOM-171-01AL | 6 | 19 | 1.43.48 | 54.4 | 168.6 | 5.0 | 4.0 | 4.5 | --- | 33 | D | 16 | P |
| KUR-171-22AL | 6 | 19 | 22.41.42 | 48.0 | 157.0 | 4.1 | )2.2 | )2.2 | KAM | -- | ND | 10 | L |
| ERS-172-09AL | 6 | 20 | 9.18. 9 | 52.0 | 131.0 | 3.7 | )2.2 | 2.7 | --- | -- | D | 16 | L |

## COMPLETE LIST OF EVENTS USED IN ALPA EVALUATION
## (PAGE 15 OF 20)

| Event Name | Mo | Day | Origin Time | Lat °N | Long °E | $m_b$ | $(M_s)R$ | $(M_s)L$ | Reg | D | Det | NS | IS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| KIR-172-15AL | 6 | 20 | 15.34.37 | 32.0 | 75.0 | 3.6 | 3.1 | 3.1 | CA | -- | D | 16 | N |
| KAM-173-000C | 6 | 21 | 0.12.58 | 53.0 | 161.0 | 4.3 | 2.7 | 2.4 | KAM | -- | D | 11 | N |
| TUR-173-05TD | 6 | 21 | 5. 6.17 | 40.2 | 30.0 | 4.1 | C2.8 | C2.8 | GT | -- | D | 15 | P |
| KAM-173-100C | 6 | 21 | 10.42.45 | 54.0 | 161.0 | 4.3 | 2.6 | 2.7 | KAM | -- | D | 15 | L |
| TUR-175-040C | 6 | 23 | 4.25.27 | 41.0 | 30.0 | 3.7 | )2.8 | )2.8 | GT | -- | ND | 14 | L |
| IIQ-175-08AL | 6 | 23 | 9.39.36 | 32.9 | 46.2 | 4.6 | 3.2 | 3.3 | CSP | 40 | D | 17 | P |
| TSK-175-16AL | 6 | 23 | 16.59.48 | 37.0 | 75.0 | 3.7 | )2.7 | )2.6 | CA | -- | ND | 14 | N |
| IRA-176-06AL | 6 | 24 | 6.57. 2 | 28.0 | 54.0 | 3.5 | )3.0 | )3.0 | SIR | -- | ND | 13 | N |
| YUG-176-070C | 6 | 24 | 7.17.56 | 43.7 | 16.9 | *4.5 | 2.9 | 2.9 | GT | 33 | D | 12 | P |
| HIN-176-150C | 6 | 24 | 15.29.22 | 36.2 | 69.7 | 6.0 | 6.0 | 5.9 | CA | 47 | D | 13 | P |
| YUG-177-04AL | 6 | 25 | 4.59.19 | 44.0 | 15.8 | *3.7 | )2.8 | )2.7 | GT | 33 | ND | 15 | P |
| HIN-177-07AL | 6 | 25 | 7.55.45 | 36.3 | 69.6 | 4.7 | 4.0 | 4.1 | CA | 46 | D | 16 | P |
| KAM-177-17AL | 6 | 25 | 17.35.50 | 54.0 | 160.0 | 4.1 | 3.4 | 3.4 | KAM | -- | D | 14 | L |
| TWN-178-080C | 6 | 26 | 8. 9.25 | 21.1 | 120.3 | 5.0 | 4.0 | 4.1 | TWN | 33 | D | 13 | P |
| KAM-178-170C | 6 | 26 | 17.32.32 | 56.0 | 158.0 | 3.6 | )2.4 | )2.6 | --- | -- | ND | 14 | L |
| HIN-178-20AL | 6 | 26 | 20.59. 3 | 36.0 | 69.0 | 3.7 | 2.9 | 3.1 | CA | -- | D | 11 | N |
| AUB-179-05AL | 6 | 27 | 5. 7.42 | 38.0 | 65.0 | 4.0 | )2.6 | )2.7 | CA | -- | ND | 15 | N |
| PAK-179-060C | 6 | 27 | 6.39.44 | 29.7 | 70.3 | 5.5 | 4.1 | 4.0 | --- | 12 | D | 14 | P |
| KAM-179-06AL | 6 | 27 | 6.49. 3 | 54.0 | 159.0 | 3.8 | 2.6 | 2.5 | KAM | -- | D | 15 | L |
| BUR-179-09AL | 6 | 27 | 9. 5.53 | 26.2 | 96.6 | 4.4 | 3.9 | 4.3 | CA | 23 | D | 13 | P |
| PAK-179-10AL | 6 | 27 | 10.48.56 | 29.7 | 70.3 | *5.2 | 3.6 | 3.5 | --- | 8 | D | 16 | P |
| HIN-179-15AL | 6 | 27 | 15.59.35 | 36.3 | 69.5 | 5.1 | 4.1 | 4.0 | CA | 53 | D | 13 | P |
| TSI-180-03AL | 6 | 28 | 3. 9.59 | 33.0 | 91.0 | 3.6 | 2.9 | 3.2 | CA | -- | D | 12 | N |
| KOM-180-04AL | 6 | 28 | 4.48.22 | 56.0 | 165.0 | 4.2 | 2.1 | 2.6 | KAM | -- | D | 12 | L |
| KOM-180-06AL | 6 | 28 | 6. 0.22 | 55.0 | 164.0 | 3.4 | )2.0 | )2.0 | KAM | -- | ND | 15 | L |
| CYP-180-08AL | 6 | 28 | 8.16.55 | 35.0 | 32.0 | 4.3 | )2.8 | )2.7 | GT | -- | ND | 14 | N |
| UAR-180-10AL | 6 | 28 | 9.49.35 | 27.6 | 33.8 | 5.6 | 4.9 | 4.6 | --- | -- | D | 14 | P |
| KAM-180-14AL | 6 | 28 | 14.58.49 | 53.0 | 161.0 | 3.9 | 2.2 | 2.4 | KAM | -- | D | 18 | L |

## COMPLETE LIST OF EVENTS USED IN ALPA EVALUATION
## (PAGE 16 OF 20)

| Event Name | Mo | Day | Origin Time | Lat °N | Long °E | $m_b$ | $(M_s)_R$ | $(M_s)_L$ | Reg | D | Det | NS | IS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CKZ-181-000C | 6 | 29 | 0.41. 2 | 54.0 | 69.0 | 3.7 | <2.7 | <2.7 | --- | -- | ND | 7 | L |
| AUB-181-030C | 6 | 29 | 3.32.11 | 38.9 | 71.4 | *4.6 | 3.9 | 3.8 | CA | 53 | D | 12 | P |
| IRA-182-170C | 6 | 30 | 17.49.33 | 27.2 | 56.8 | 4.6 | 3.4 | 3.5 | SIR | N | D | 5 | P |
| TWN-182-18TD | 6 | 30 | 18.57.43 | 24.3 | 121.1 | 4.9 | 3.7 | 3.9 | TWN | 33 | D | 11 | P |
| KOM-183-02AL | 7 | 1 | 2.10.18 | 54.0 | 166.0 | 3.4 | 2.4 | 2.3 | KAM | -- | D | 14 | L |
| IRA-184-12AL | 7 | 2 | 12.56. 7 | 30.1 | 50.9 | 5.4 | 5.2 | 4.8 | SIR | 31 | D | 8 | P |
| IRA-184-14AL | 7 | 2 | 14. 5. 6 | 30.0 | 50.8 | 4.6 | 3.5 | 3.3 | SIR | 31 | D | 14 | P |
| IIQ-185-19AL | 7 | 3 | 19.26.22 | 32.0 | 48.0 | 4.0 | <3.1 | <2.9 | CSP | -- | ND | 10 | N |
| IRA-185-21TD | 7 | 3 | 21.38.22 | 30.0 | 51.0 | 5.1 | 4.0 | 3.7 | SIR | 43 | D | 10 | P |
| TUR-186-06AL | 7 | 4 | 6.17.25 | 41.0 | 33.0 | 3.4 | <2.8 | <2.8 | GT | -- | ND | 13 | L |
| IRA-186-09AL | 7 | 4 | 9.28. 7 | 28.0 | 54.0 | 3.9 | <3.0 | <2.8 | SIR | -- | ND | 14 | N |
| KAM-186-13AL | 7 | 4 | 13.52.19 | 55.0 | 163.0 | 4.4 | 2.7 | 2.4 | KAM | -- | D | 13 | L |
| SIN-187-01AL | 7 | 5 | 1. 9.53 | 44.6 | 81.1 | 4.6 | 3.9 | 4.1 | CA | N | D | 13 | P |
| SIN-187-02AL | 7 | 5 | 2.41.54 | 44.0 | 86.0 | 3.5 | <2.8 | <2.8 | CA | -- | ND | 10 | N |
| SIN-187-04AL | 7 | 5 | 4. 9.49 | 43.6 | 87.9 | 4.3 | 3.2 | 3.1 | CA | N | D | 11 | P |
| IRA-187-16AL | 7 | 5 | 16.29.27 | 31.0 | 52.0 | 4.0 | 2.9 | 3.0 | SIR | -- | D | 14 | N |
| MED-187-18AL | 7 | 5 | 18. 4.54 | 36.9 | 21.5 | 4.7 | 3.0 | 3.1 | GT | 17 | D | 15 | P |
| IRA-187-21AL | 7 | 5 | 21.41. 8 | 30.0 | 54.0 | 4.1 | 2.9 | <2.9 | SIR | -- | D | 12 | N |
| EKZ-188-01AL | 7 | 6 | 1. 2.58 | 49.7 | 78.0 | 4.4 | <2.6 | <2.6 | EKZ | 00 | ND | 13 | XP |
| IRA-188-05AL | 7 | 6 | 5.41.43 | 27.0 | 55.0 | 3.1 | <2.9 | <2.7 | SIR | -- | D | 12 | N |
| RYU-192-00AL | 7 | 10 | 0.41.23 | 28.0 | 130.6 | 4.1 | <2.6 | <3.0 | --- | 30 | D | 6 | P |
| KAM-192-12AL | 7 | 10 | 12.26.31 | 53.6 | 161.7 | 4.1 | 2.7 | 3.3 | KAM | 33 | D | 15 | P |
| SIN-192-19AL | 7 | 10 | 19. 3.33 | 43.4 | 88.6 | 4.7 | 3.5 | 3.6 | CA | 33 | D | 13 | P |
| AUB-193-04AL | 7 | 11 | 4.20.41 | 37.0 | 72.0 | 4.2 | <2.9 | <2.9 | CA | -- | ND | 11 | L |
| KAM-193-08OC | 7 | 11 | 8.53.49 | 55.0 | 163.0 | 3.6 | 2.5 | 2.6 | KAM | -- | D | 9 | L |
| IIQ-193-22AL | 7 | 11 | 22.49. 2 | 36.1 | 45.7 | 4.7 | 3.3 | 3.4 | CSP | N | D | 11 | P |
| KUR-194-000C | 7 | 12 | 0.14.27 | 49.3 | 155.4 | 5.2 | 3.6 | 3.3 | KAM | N | D | 14 | P |
| TIB-195-05AL | 7 | 13 | 5.27.44 | 31.0 | 89.0 | 3.9 | <3.2 | <3.2 | CA | -- | ND | 12 | N |

## COMPLETE LIST OF EVENTS USED IN ALPA EVALUATION
## (PAGE 17 OF 20)

| Event Name | Mo | Day | Origin Time | Lat °N | Long °E | $m_b$ | $(M_s)_R$ | $(M_s)_L$ | Reg | D | Det | NS | IS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PAK-194-01AL | 7 | 12 | 1.21.18 | 33.0 | 73.0 | 3.5 | )3.1 | )3.1 | CA | -- | ND | 13 | N |
| KUR-195-15AL | 7 | 13 | 15. 5.44 | 44.0 | 150.0 | 4.2 | 3.0 | 2.9 | KUR | -- | D | 12 | N |
| TWN-195-23AL | 7 | 13 | 23. 2.25 | 22.0 | 123.0 | 3.8 | 3.0 | 3.1 | TWN | -- | D | 12 | N |
| TUR-196-04AL | 7 | 14 | 4.33.45 | 36.0 | 31.0 | 3.9 | )3.0 | )2.9 | GT | -- | ND | 12 | N |
| IRA-196-130C | 7 | 14 | 13. 4.12 | 30.1 | 50.8 | 4.4 | 3.3 | 3.0 | SIR | 34 | D | 13 | P |
| IRA-196-17AL | 7 | 14 | 17.49.13 | 30.0 | 51.0 | 3.4 | C2.8 | 3.0 | SIR | -- | D | 12 | N |
| RYU-196-18AL | 7 | 14 | 18.50.33 | 30.0 | 132.0 | 3.9 | )2.5 | )2.8 | --- | -- | ND | 14 | L |
| KGZ-197-00AL | 7 | 15 | 0.35.52 | 43.0 | 78.0 | 3.8 | C2.8 | C2.7 | CA | -- | D | 11 | N |
| RYU-197-02AL | 7 | 15 | 2.15.42 | 24.2 | 125.1 | 5.1 | 3.8 | 3.6 | TWN | 29 | D | 13 | P |
| KUR-197-09AL | 7 | 15 | 9.51.51 | 47.0 | 152.0 | 4.4 | 2.5 | 2.5 | KUR | -- | D | 15 | L |
| KAM-197-13AL | 7 | 15 | 13.50. 4 | 53.0 | 157.0 | 3.7 | 2.2 | 2.4 | KAM | -- | D | 14 | L |
| KUR-197-17AL | 7 | 15 | 17.25.37 | 46.0 | 149.0 | 3.5 | )2.4 | )2.4 | KUR | -- | ND | 13 | L |
| TIB-198-02AL | 7 | 16 | 2.20.24 | 32.5 | 95.9 | 5.2 | 3.9 | 3.9 | CA | N | D | 13 | P |
| TUR-198-02AL | 7 | 16 | 2.46.51 | 38.3 | 43.3 | 4.9 | 4.4 | 4.2 | CSP | 40 | D | 15 | P |
| TIB-198-03AL | 7 | 16 | 3.40. 0 | 32.6 | 95.8 | 4.7 | 3.5 | 3.6 | CA | N | D | 17 | P |
| TWN-198-13AL | 7 | 16 | 13.48. 5 | 23.7 | 121.3 | 4.6 | 3.2 | 3.4 | TWN | N | D | 16 | P |
| KAM-198-20AL | 7 | 16 | 20. 4. 4 | 54.4 | 162.9 | 4.2 | 2.9 | 2.7 | KAM | N | D | 14 | P |
| MED-199-03AL | 7 | 17 | 3.14. 5 | 34.0 | 30.0 | 3.9 | 3.1 | )3.0 | GT | -- | D | 14 | L |
| KAM-199-08AL | 7 | 17 | 8.28.52 | 55.0 | 159.6 | 5.3 | 3.9 | 4.3 | KAM | N | D | 12 | P |
| KAM-199-11AL | 7 | 17 | 11.11.46 | 57.0 | 162.0 | 3.3 | )2.0 | )2.0 | KAM | -- | ND | 13 | L |
| KAM-199-20AL | 7 | 17 | 20.50.54 | 55.1 | 159.5 | 4.5 | 2.6 | 3.0 | KAM | N | D | 11 | P |
| SIN-200-03AL | 7 | 18 | 3.27. 7 | 39.0 | 77.0 | 4.0 | C2.7 | 2.9 | CA | -- | D | 17 | N |
| CKZ-200-06AL | 7 | 18 | 6. 4.53 | 51.0 | 66.0 | 3.7 | )2.6 | )2.7 | --- | -- | ND | 17 | L |
| GRU-200-13AL | 7 | 18 | 13.45.48 | 41.6 | 22.8 | 4.0 | 3.0 | 2.9 | GT | N | D | 17 | P |
| AUB-201-19AL | 7 | 19 | 19.43.40 | 38.0 | 70.0 | 3.6 | )2.8 | )2.8 | CA | -- | ND | 13 | N |
| TIB-202-10AL | 7 | 20 | 10. 4.18 | 28.0 | 91.0 | 3.9 | 2.9 | 3.1 | CA | -- | D | 14 | N |
| IRA-202-13AL | 7 | 20 | 13.58.43 | 36.0 | 55.0 | 4.3 | 3.4 | 3.6 | CSP | -- | D | 16 | N |
| CRM-204-05AL | 7 | 22 | 5.10.40 | 44.9 | 36.9 | 4.6 | 3.8 | 3.3 | --- | N | D | 18 | P |

## COMPLETE LIST OF EVENTS USED IN ALPA EVALUATION
(PAGE 18 OF 20)

| Event Name | Mo | Day | Origin Time | Lat °N | Long °E | $m_b$ | $(M_s)_R$ | $(M_s)_L$ | Reg | D | Det | NS | IS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TIB-204-16AL | 7 | 22 | 16.41. 4 | 31.4 | 91.5 | 5.5 | 4.9 | 5.2 | CA | N | D | 16 | P |
| TIB-204-21AL | 7 | 22 | 21. 0. 9 | 31.4 | 91.4 | 4.7 | 3.0 | 3.0 | CA | N | D | 13 | P |
| MED-205-18AL | 7 | 23 | 18.17.25 | 33.0 | 24.0 | 3.9 | )2.9 | )3.1 | GT | -- | ND | 10 | L |
| TIB-205-23AL | 7 | 23 | 23.41.55 | 31.0 | 91.0 | 3.6 | )3.2 | )3.3 | CA | -- | ND | 8 | N |
| KAM-206-10AL | 7 | 24 | 10.14.35 | 58.0 | 159.0 | 3.7 | 2.8 | 3.3 | --- | -- | D | 9 | L |
| TUR-206-10AL | 7 | 24 | 10.22.23 | 39.4 | 40.1 | 4.4 | 3.0 | 3.2 | --- | N | D | 11 | P |
| KTB-206-14AL | 7 | 24 | 14.58.14 | 35.8 | 80.6 | 4.8 | 3.6 | 3.2 | CA | N | D | 12 | P |
| GRE-207-01QC | 7 | 25 | 1.56. 7 | 38.7 | 21.4 | 4.5 | )3.2 | C3.2 | GT | 45 | D | 10 | P |
| CAU-208-18AL | 7 | 26 | 18.57.25 | 40.0 | 47.0 | 4.0 | 3.1 | 3.0 | CSP | -- | D | 8 | N |
| KUR-209-00AL | 7 | 27 | 0.20.55 | 50.0 | 159.1 | 5.1 | 4.0 | 4.0 | KAM | N | D | 15 | P |
| RYU-209-16AL | 7 | 27 | 16.41.30 | 25.4 | 130.5 | 5.1 | 4.3 | 4.2 | --- | N | D | 13 | P |
| DOD-211-08AL | 7 | 29 | 8.22.17 | 37.0 | 29.0 | 3.8 | )2.8 | )2.8 | GT | -- | ND | 17 | L |
| AFG-211-17AL | 7 | 29 | 17.10.35 | 32.0 | 68.0 | 3.8 | 3.1 | 3.2 | CA | -- | D | 17 | N |
| KUR-211-21AL | 7 | 29 | 21. 7.16 | 49.2 | 156.2 | 4.8 | 3.4 | 3.5 | KAM | N | D | 15 | P |
| TWN-212-16AL | 7 | 30 | 16. 0. 3 | 21.2 | 121.3 | 4.9 | 3.7 | 3.8 | TWN | N | D | 15 | P |
| KAM-213-06AL | 7 | 31 | 6.40.28 | 56.2 | 162.9 | 4.8 | 3.2 | 3.4 | KAM | N | D | 17 | P |
| IRA-213-21AL | 7 | 31 | 21. 1.25 | 31.0 | 52.0 | 3.6 | )2.8 | )2.9 | SIR | -- | ND | 12 | N |
| RYU-214-05AL | 8 | 1 | 5.33.41 | 30.0 | 131.0 | 3.7 | 2.8 | 2.7 | --- | -- | D | 15 | L |
| PAK-214-09AL | 8 | 1 | 9.44.47 | 36.0 | 72.0 | 4.1 | )2.6 | )2.7 | CA | -- | ND | 16 | N |
| TUR-216-02AL | 8 | 3 | 2. 4.26 | 37.8 | 32.5 | 4.3 | 3.1 | )3.1 | GT | 28 | D | 12 | P |
| KUR-216-02QC | 8 | 3 | 2.25.23 | 46.9 | 152.6 | 4.5 | 2.7 | 2.8 | KUR | N | D | 10 | P |
| KAM-216-03AL | 8 | 3 | 3.57.16 | 56.0 | 162.0 | 4.0 | 2.9 | 2.7 | KAM | -- | D | 10 | L |
| TUR-216-21AL | 8 | 3 | 21.39.26 | 37.7 | 32.7 | 4.5 | 3.7 | 3.6 | GT | 41 | D | 14 | P |
| IRA-216-22AL | 8 | 3 | 22.47.46 | 28.2 | 57.0 | 4.8 | 3.6 | 3.6 | SIR | 62 | D | 10 | P |
| KUR-217-04AL | 8 | 4 | 4.30.30 | 47.0 | 151.0 | 4.0 | )2.5 | )2.6 | KUR | -- | ND | 14 | L |
| TUR-217-05AL | 8 | 4 | 5.30. 0 | 37.9 | 32.9 | 4.3 | 3.1 | C3.1 | GT | N | D | 14 | P |
| KUR-218-22AL | 8 | 5 | 22.11.52 | 49.0 | 155.0 | 3.8 | 2.5 | 2.8 | KAM | -- | D | 13 | L |
| MED-219-03AL | 8 | 6 | 3.45. 7 | 34.0 | 29.0 | 4.0 | )2.8 | )2.8 | GT | -- | ND | 15 | L |

## COMPLETE LIST OF EVENTS USED IN ALPA EVALUATION
## (PAGE 19 OF 20)

| Event Name | Mo | Day | Origin Time | Lat °N | Long °E | $m_b$ | $(M_s)_R$ | $(M_s)_L$ | Reg | D | Det | NS | IS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TUR-220-05AL | 8 | 7 | 5.42.48 | 38.0 | 32.0 | 4.0 | M2.9 | <2.7 | GT | -- | D | 15 | L |
| PAK-221-14AL | 8 | 8 | 14.24.18 | 26.0 | 63.0 | 4.2 | 3.0 | 2.9 | --- | -- | D | 13 | N |
| IRA-221-19AL | 8 | 8 | 19. 9.34 | 25.0 | 61.1 | 5.5 | 4.6 | 4.6 | --- | 41 | D | 15 | P |
| KUR-222-10AL | 8 | 9 | 10.34.54 | 49.0 | 153.0 | 4.1 | <2.1 | <2.1 | --- | -- | ND | 13 | L |
| ERS-222-20AL | 8 | 9 | 20.51.51 | 56.8 | 127.2 | 4.8 | 4.0 | 4.4 | --- | 36 | D | 6 | P |
| KOM-223-14AL | 8 | 10 | 14. 7.13 | 55.0 | 166.0 | 3.5 | <2.1 | <2.2 | KAM | -- | ND | 8 | L |
| ITY-224-06AL | 8 | 11 | 6.49. 5 | 41.0 | 14.0 | 4.0 | <2.9 | <3.0 | GT | -- | ND | 16 | L |
| KUR-228-22AL | 8 | 15 | 22.51.37 | 47.0 | 151.0 | 4.1 | <2.3 | <2.5 | KUR | -- | ND | 8 | L |
| KAM-229-01AL | 8 | 16 | 1.44.47 | 55.0 | 164.0 | 3.4 | 2.2 | 2.4 | KAM | -- | D | 7 | L |
| EKZ-229-030C | 8 | 16 | 3.16.57 | 49.8 | 78.1 | 5.2 | M2.5 | M2.5 | EKZ | 00 | D | 7 | XP |
| IRA-229-05AL | 8 | 16 | 5.42.23 | 36.0 | 49.0 | 3.5 | M2.8 | M3.0 | CSP | -- | D | 7 | N |
| KOM-229-08AL | 8 | 16 | 8.21.14 | 55.0 | 164.0 | 3.6 | 2.4 | 2.3 | KAM | -- | D | 7 | L |
| KOM-229-100C | 8 | 16 | 10.26.59 | 55.0 | 165.5 | 4.3 | 3.1 | 3.4 | KAM | N | D | 7 | P |
| KAM-229-21AL | 8 | 16 | 21.37.19 | 56.0 | 163.0 | 3.6 | 2.2 | 2.1 | KAM | -- | D | 8 | L |
| RYU-231-18AL | 8 | 18 | 18.42.19 | 23.8 | 126.6 | 4.8 | 3.9 | 3.8 | TWN | N | D | 11 | P |
| KAM-231-18AL | 8 | 18 | 18.50.18 | 55.0 | 163.0 | 4.0 | 2.6 | 2.6 | KAM | -- | D | 14 | L |
| KAM-231-19AL | 8 | 18 | 19. 2. 1 | 53.0 | 159.9 | 5.1 | 3.3 | 3.2 | KAM | N | D | 10 | P |
| KUR-231-23AL | 8 | 18 | 23.23.18 | 50.0 | 153.0 | 3.7 | 2.4 | <2.4 | --- | -- | D | 14 | L |
| BIB-232-04AL | 8 | 19 | 4.20.41 | 22.0 | 94.0 | 3.9 | <2.7 | <2.7 | CA | -- | ND | 16 | N |
| GRF-232-06AL | 8 | 19 | 6.46.56 | 38.0 | 23.0 | 3.6 | M2.7 | <2.6 | GT | -- | D | 16 | L |
| KUR-232-21AL | 8 | 19 | 21.56.10 | 45.0 | 149.0 | 3.5 | M2.4 | M2.5 | KUR | -- | D | 12 | L |
| KUR-232-23AL | 8 | 19 | 23.20.48 | 43.5 | 148.4 | 4.9 | 3.6 | 4.1 | KUR | 39 | D | 7 | P |
| WKZ-233-020C | 8 | 20 | 2.59.58 | 49.5 | 48.2 | 5.7 | 2.8 | 3.0 | --- | 00 | D | 10 | XP |
| KAM-233-080C | 8 | 20 | 8.10. 8 | 51.3 | 161.6 | 5.2 | 3.8 | 4.2 | KAM | N | D | 9 | P |
| KUR-234-13AL | 8 | 21 | 13.45.49 | 47.0 | 151.0 | 4.0 | <2.3 | <2.2 | KUR | -- | ND | 13 | L |
| SIK-234-14AL | 8 | 21 | 14. 4.34 | 27.2 | 88.0 | 4.8 | 3.5 | 3.8 | CA | N | D | 12 | P |
| CRF-235-02AL | 8 | 22 | 2.44.10 | 35.0 | 25.0 | 4.0 | <2.7 | 2.8 | GT | -- | D | 14 | L |
| KUR-235-03AL | 8 | 22 | 3.37. 0 | 47.0 | 153.0 | 4.1 | C2.1 | <2.2 | KUR | -- | D | 14 | L |

## COMPLETE LIST OF EVENTS USED IN ALPA EVALUATION
## (PAGE 20 OF 20)

| Event Name | Mo | Day | Origin Time | Lat °N | Long °E | $m_b$ | $(M_s)_R$ | $(M_s)_L$ | Reg | D | Det | NS | IS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| KUR-235-14AL | 8 | 22 | 14.20.19 | 50.2 | 156.7 | 5.2 | 4.0 | 3.7 | KAM | 63 | D | 8 | P |
| KUR-236-10AL | 8 | 23 | 10.38. 8 | 49.0 | 156.0 | 3.7 | 2.2 | 2.2 | KAM | -- | D | 16 | L |
| TUR-236-21AL | 8 | 23 | 21.14.16 | 39.0 | 29.0 | 4.0 | 2.8 | 2.8 | GT | -- | D | 15 | L |
| KAM-237-17AL | 8 | 24 | 17. 5.56 | 53.0 | 160.0 | 3.8 | )2.0 | )2.1 | KAM | -- | D | 13 | L |
| KUR-237-22AL | 8 | 24 | 22.54.19 | 48.0 | 147.0 | 3.8 | )2.2 | )2.1 | --- | -- | ND | 14 | L |
| SIB-238-04AL | 8 | 25 | 4.11.20 | 71.0 | 138.0 | 4.0 | 2.1 | 2.2 | --- | -- | D | 17 | L |
| TUR-240-01AL | 8 | 27 | 1.14.57 | 38.0 | 30.0 | 3.6 | )2.8 | )2.6 | GT | -- | ND | 17 | N |
| HIN-240-16AL | 8 | 27 | 16.54. 1 | 36.0 | 70.0 | 3.6 | )2.6 | )2.5 | CA | -- | ND | 16 | N |
| KAM-241-02AL | 8 | 28 | 2.39. 6 | 56.0 | 163.0 | 4.2 | 2.8 | 2.4 | KAM | -- | D | 16 | L |
| NVZ-241-05AL | 8 | 28 | 5.59.56 | 73.3 | 55.1 | 6.3 | 4.4 | 4.2 | --- | 00 | D | 15 | XP |
| KUR-241-09AL | 8 | 28 | 9. 0.22 | 49.0 | 155.0 | 3.7 | )2.2 | )2.2 | KAM | -- | D | 15 | L |
| MED-242-21AL | 8 | 29 | 21.59.23 | 33.0 | 27.0 | 4.4 | 3.4 | 3.0 | GT | -- | D | 15 | L |
| TIB-242-23AL | 8 | 29 | 23. 0.21 | 34.0 | 82.0 | 3.7 | )3.0 | )2.8 | CA | -- | ND | 14 | N |
| YUG-243-00AL | 8 | 30 | 0. 8.23 | 44.0 | 16.2 | 4.5 | 3.0 | 2.9 | GT | N | D | 14 | P |
| TSI-243-15AL | 8 | 30 | 15.14.10 | 36.7 | 96.5 | 5.5 | 4.9 | 4.8 | CA | N | D | 11 | P |
| SIN-243-17AL | 8 | 30 | 17.52.23 | 40.0 | 94.0 | 4.2 | 3.1 | 3.0 | CA | -- | D | 15 | N |
| KAM-243-20AL | 8 | 30 | 20. 6.50 | 53.0 | 160.0 | 4.6 | 2.6 | 2.7 | KAM | -- | D | 9 | L |
| CRS-244-14AL | 8 | 31 | 14. 3.16 | 52.3 | 95.4 | 5.5 | 4.5 | 4.2 | --- | N | D | 11 | P |
| MON-244-17AL | 8 | 31 | 17.22.47 | 49.0 | 106.0 | 3.7 | )2.6 | )2.7 | --- | -- | ND | 8 | L |
| KAM-244-18AL | 8 | 31 | 18.12. 8 | 55.0 | 163.0 | 3.5 | )2.2 | 2.9 | KAM | -- | D | 8 | L |
| EKZ-246-08AL | 9 | 2 | 8.56.58 | 50.0 | 77.0 | 5.1 | )2.5 | )2.4 | EKZ | -- | ND | 12 | XP |
| SWR-277-08AL | 10 | 3 | 8.59.58 | 46.8 | 45.0 | 5.8 | 2.7 | 2.7 | --- | 00 | D | 14 | XP |
| EKZ-307-01AL | 11 | 2 | 1.26.58 | 49.9 | 78.8 | 6.2 | 3.7 | 3.6 | EKZ | 00 | D | 14 | XP |
| EKZ-345-04AL | 12 | 10 | 4.26.58 | 49.8 | 78.1 | 5.7 | 4.2 | 4.1 | EKZ | 00 | D | 15 | XP |

## APPENDIX B

## DISPOSITION OF EVENTS PROPOSED FOR ROUTINE PROCESSING

A breakdown of the disposition of events is presented in the table below.

| Month | Total Number of Events Proposed For Processing | Processing Completed | Not Completed Due To Interference | Not Completed Due To Tape and Data Problems |
|---|---|---|---|---|
| January | 81 | 67% | 17% | 16% |
| February | 131 | 57% | 34% | 9% |
| March | 84 | 48% | 18% | 34% |
| June | 122 | 65% | 19% | 16% |
| July | 112 | 62% | 12% | 26% |
| August* | 146 | 44% | 27% | 29% |

* The processing of August events was not completed due to time restraints. The percentages are based on the number of events for which processing was attempted (132).

The term "interference" as used here is defined in Quarterly Report No. 3.

Tape and data problems include parity errors, uncorrectable spikes, and data not on tape.

# APPENDIX C

## NOISE ANALYSIS PARAMETERS
## 1972 NOISE SAMPLES

| Day | Start Time | No. of Sites Available | Frequency | Azimuth | Velocity km/sec |
|---|---|---|---|---|---|
| 1 | 08.20.00 | 11 | .055 | 135° | 3.9 |
| 12 | 22.20.00 | 8 | .063 | 225° | 3.6 |
| 21 | 04.50.00 | 13 | .059 | 148° | 3.5 |
| 31 | 14.00.00 | 11 | .063 | 237° | 3.8 |
| 41 | 22 00.00 | 15 | .063 | 127° | 3.6 |
| 51 | 23.15.00 | 15 | .059 | 178° | 3.5 |
| 61 | 08.00.00 | 10 | .051 | 19° | 4.0 |
| 71 | 14.40.00 | 13 | .051 | 145° | 3.8 |
| 81 | 21.20.00 | 11 | .059 | 172° | 3.6 |
| 90 | 01.30.00 | 9 | .063 | 189° | 3.7 |
| 101 | 19.20.00 | 13 | .055 | 27° | 3.9 |
| 111 | 23.00.00 | 10 | .055 | 211° | 3.8 |
| 121 | 23.15.00 | 10 | .059 | 140° | 3.6 |
| 131 | 00.55.00 | 9 | .055 | 141° | 3.9 |
| 142 | 09.45.00 | 7 | .063 | 222° | 3.8 |
| 152 | 02.20.00 | 10 | .051 | 207° | 3.9 |
| 161 | 22.30.00 | 12 | .059 | 143° | 3.8 |
| 172 | 20.55.00 | 13 | .051 | 232° | 3.6 |
| 181 | 02.25.00 | 11 | .055 | 163° | 3.9 |
| 191 | 00.45.00 | 7 | .055 | 288° | 3.8 |
| 201 | 00.15.00 | 15 | .051 | 141° | 3.6 |
| 211 | 15.00.00 | 16 | .055 | 140° | 3.6 |
| 220 | 18.38.00 | 9 | .059 | 209° | 3.6 |
| 232 | 20.40.00 | 11 | .059 | 288° | 3.7 |
| 241 | 01.10.00 | 16 | .059 | 215° | 3.6 |
| 250 | 10.30.00 | 12 | .055 | 188° | 3.5 |
| 261 | 08.20.00 | 11 | .059 | 288° | 3.8 |
| 272 | 14.10.00 | 11 | .047 | 89° | 3.7 |
| 281 | 10.50.00 | 12 | .059 | 180° | 3.5 |
| 291 | 20.30.00 | 14 | .063 | 139° | 3.8 |

| Day | Start Time | No. of Sites Available | Frequency | Azimuth | Velocity km/sec |
|---|---|---|---|---|---|
| 301 | 22.40.00 | 11 | .059 | 192° | 3.5 |
| 311 | 08.40.00 | 15 | .055 | 48° | 3.8 |
| 321 | 10.20.00 | 10 | .059 | 143° | 3.8 |
| 331 | 20.20.00 | 15 | .063 | 141° | 3.6 |
| 341 | 17.50.00 | 15 | .055 | 0° | 3.6 |
| 352 | 19.45.00 | 9 | .055 | 68° | 3.7 |
| 361 | 15.30.00 | 16 | .063 | 135° | 3.6 |